ELECTRONICS FOR MEASUREMENT • COMPUTATION • TELEMETRY • CONTROL

INSTRUCTION MANUAL

for

FM SUBCARRIER DEMODULATOR

MODEL GFD-13

DAI

DCS DATA-CONTROL SYSTEMS INC.

Instrumentation for Research

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DRO 222217

DIFFERENCE DATA

GFD-13 INSTRUCTION MANUAL

FM SUBCARRIER DEMODULATOR, MODEL GFD-13

GFD-13-01 versus GFD-13

The GFD-13-01 differs from the standard GFD-13 unit in the following changes in the output stage:

Maximum Output Frequency Response:	250 kHz
Normal Output Frequency Response:	200 kHz
Output Voltage Limiting:	The output level is limited to 140% of the output voltage as set on the output level control. Example: With the output level control locked on the 10V position (20V peak-to-peak) the output voltage would be limited to a max. of 140% of 10V peak (28V peak-to-peak). Example: With the output level control locked on the 2V position, the max. output voltage would be limited to 140% of 2V peak (5.6V peak-to-peak).

NOTE

1. In order to use an existing Model GFD-13/RTU (Reference Tuning Unit) with the GFD-13-01 Discriminator, it is necessary to return the Tuning Unit to the factory for modification.
2. The output level control (located on the front panel of the GFD-13-01) is used to adjust the tape speed compensation output level for optimum performance.

The following drawings are provided in Section VI

CW-018333	Schematic, Low-Pass Amplifier
AA-018203	Assembly, Low-Pass Amplifier

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INSTRUCTION MANUAL

FM SUBCARRIER DEMODULATOR

MODEL GFD-13

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COMPOSITION PAGE

INSTRUCTION MANUAL

FM SUBCARRIER DEMODULATOR

MODEL GFD-13

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Figure 1-1. FM Subcarrier Demodulator, Model GFD-13

SECTION I

DESCRIPTION AND LEADING PARTICULARS

1-1. PURPOSE AND SCOPE.

1-2. This publication contains a general description with installation, operation and maintenance instructions for the Model GFD-13 FM Subcarrier Demodulator, designed and mnaufactured by Data Control Systems, Inc., East Liberty Street, Danbury, Connecticut.

1-3. A general discussion of electrical and physical characteristics is covered in Section I. Installation is described in Section II and Section III covers operation. Section IV covers the Theory of Operation including a functional description of the equipment. Section V is Maintenance, including troubleshooting and the drawing list, and drawings, is contained in Section VI.

1-4. Material requiring clarification is illustrated with line drawings, halftones or listed in tabular form.

1-5. FM SUBCARRIER DEMODULATOR, MODEL GFD-13

1-6. The Model GFD-13 is a phase-locked loop FM demodulator compatible with all ground based systems where selection and demodulation of single wide band carriers or multiplexed signals is performed.

1-7. This unit represents a substantial advancement in electrical performance, quality, reliability and flexibility as compared to contemporary demodulators. In its design, quality has not been compromised for economy. The GFD-13 contains its own integral power supply, complete input and output metering provisions, and utilizes only silicon transistors. Design emphasis has been placed upon achieving simple and reliable circuitry in conjunction with rugged and precise mechanical construction. It has been designed to comply fully with MIL-I-26600 and similar EMI standards. The GFD-13 is provided with a full range of accessory equipments to adapt it to virtually any application. These include several types of Tuning Units and Low Pass Filters, Modular Housing and Tape Speed Compensation Units. (See Table 1-1.)

Table 1-1. GFD-13 and Subassemblies

Function	Model Designation	Description
Demodulator	GFD-13, FM Subcarrier Demodulator	Main chassis, power supply, and circuit boards. Accepts plug-in tuning units and low pass filters
Housing	GMH-13, Modular Housing	Mounts three demodulators side by side in 3-1/2" panel space. BNC input and output connectors
Tuning Units	GFD-13/TU, Standard Tuning Unit	For use with IRIG or CBW channels. ±4% to ±25% deviation. High adjacent channel rejection
	GFD-13/TU (D)	Similar to above standard but with manual output polarity switching
	GFD-13/TU (E)	Similar to above standard but with remote and manual output
	GFD-13/TUW, Wide Deviation Tuning Unit	For FM magnetic recording or special channels with deviation up to ±40%. Not normally used for multiplexed channels
	GFD-13/TUA, Adjustable Loop Filter Tuning Unit	Providing high modulation index loop filter for threshold improvement. 6 loop filter positions
	GFD-13/TUR, High Rejection Tuning Unit	Permits optimum demodulation at 70 kHz with ±30% deviation and provides very high crosstalk rejection
Low Pass Filters	GFD-13/TU/L, Standard Low Pass Filter	For use with any type channel. Specify linear phase or constant amplitude response characteristic
	GFD-13/TU/LSM, Switchable Low Pass Filter	For use with any type channel. Constant amplitude or linear phase characteristic selected by front panel switch
Tape Speed Compensation	GFD-13/RTU, Reference Tuning Unit	Replaces normal tuning unit and converts data demodulator to reference demodulator. No external delay line required
	GDL-13, Delay Line	Required only for special compensation systems where reference frequency is lower than highest data subcarrier frequency. Used in conjunction with GFD-13/ARTU
	GFD-13/ARTU, Reference Tuning Unit Adaptor	Reference tuning unit with adaptor for use with GDL-13 delay line

1-8. PHYSICAL CHARACTERISTICS. The GFD-13 is a sturdy and compact unit approximately 3-1/2 inches high. Three units mount side by side in the Model GMH-13 Housing. (See Figure 1-2.) Mating connectors on the Housing and Demodulator facilitate easy removal and replacement of all units.

1-9. All structural portions of the GFD-13 are comprised of heavy-wall aluminum extrusions which result in great strength and ruggedness in addition to a precise mechanical fit of all parts including plug-in units. All circuit boards are guided and supported by grooves which are an integral part of the main chassis extrusion.

1-10. The main chassis is a box section extrusion divided into a front and rear portion by a centrally-located plug-board. The Power Supply, Tuning Unit, Low Pass Filter, and all circuit boards are interconnected through the plug-board. This arrangement permits simplified removal of all electrical portions of the demodulator unit for maintenance or replacement purposes. (See Figure 1-2A.)

1-11. The front portion of the main chassis is divided into an upper and lower section by the tuning unit which plugs into the center of the front panel. An upper and a lower circuit board are mounted in a plane parallel to the tuning unit so that all components are clearly visible and accessible.

1-12. The tuning unit is engaged, extracted, or held in place by a very simple and easily-operated locking handle. With the tuning unit in place, the handle is flush with the front surface of the tuning unit. By pulling gently forward on the handle, the tuning unit is extracted. When the tuning unit is replaced, the handle automatically assumes a position wherein it can be pushed in flush with the tuning unit. This engages the tuning unit and locks it securely in place. The handle also locks the demodulator into its housing. When the handle is pulled forward to extract the tuning unit, the demodulator can also be pulled out of its housing.

1-13. The low pass filter plugs into the front of the tuning unit so that it can be replaced without removing the tuning unit. The low pass filter is removed by pushing a small button on its front panel. When the tuning unit is removed, the low pass filter remains locked into it, but can be removed by activating the pushbutton.

1-14. The rear portion of the main chassis contains the power supply and the output amplifier board. These are plug-in assemblies which may be removed separately or as a unit. The power supply assembly provides all mating connection between the demodulator and the housing.

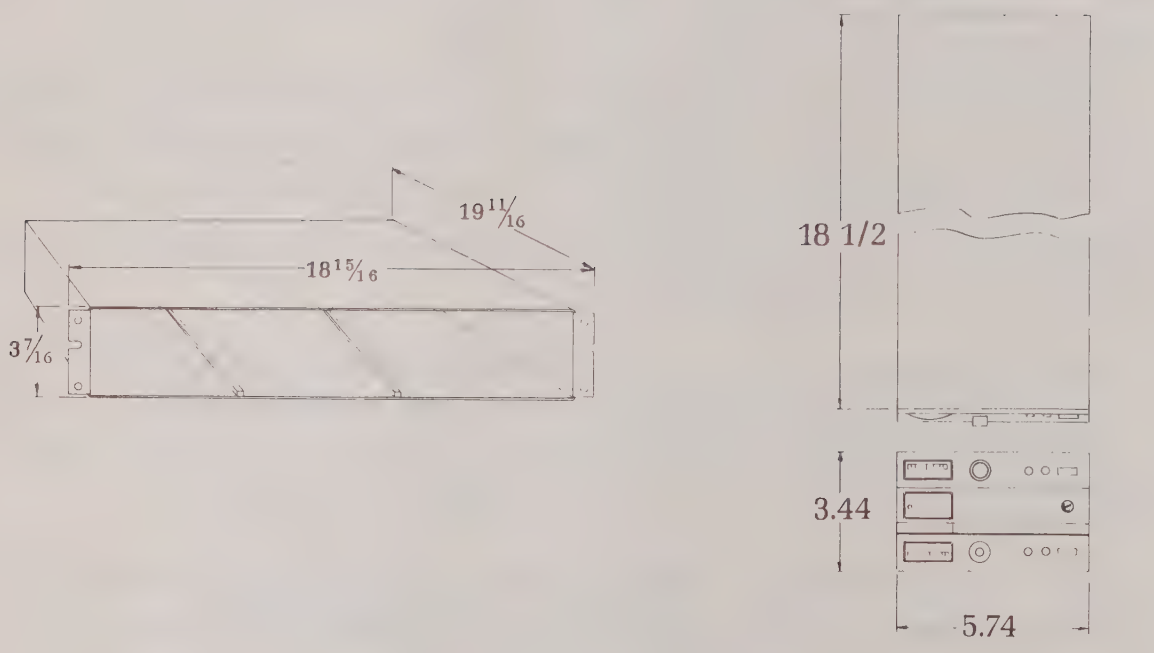


Figure 1-2. Outline Drawing of GFD-13 FM Subcarrier Demodulator and GMH-13 Housing

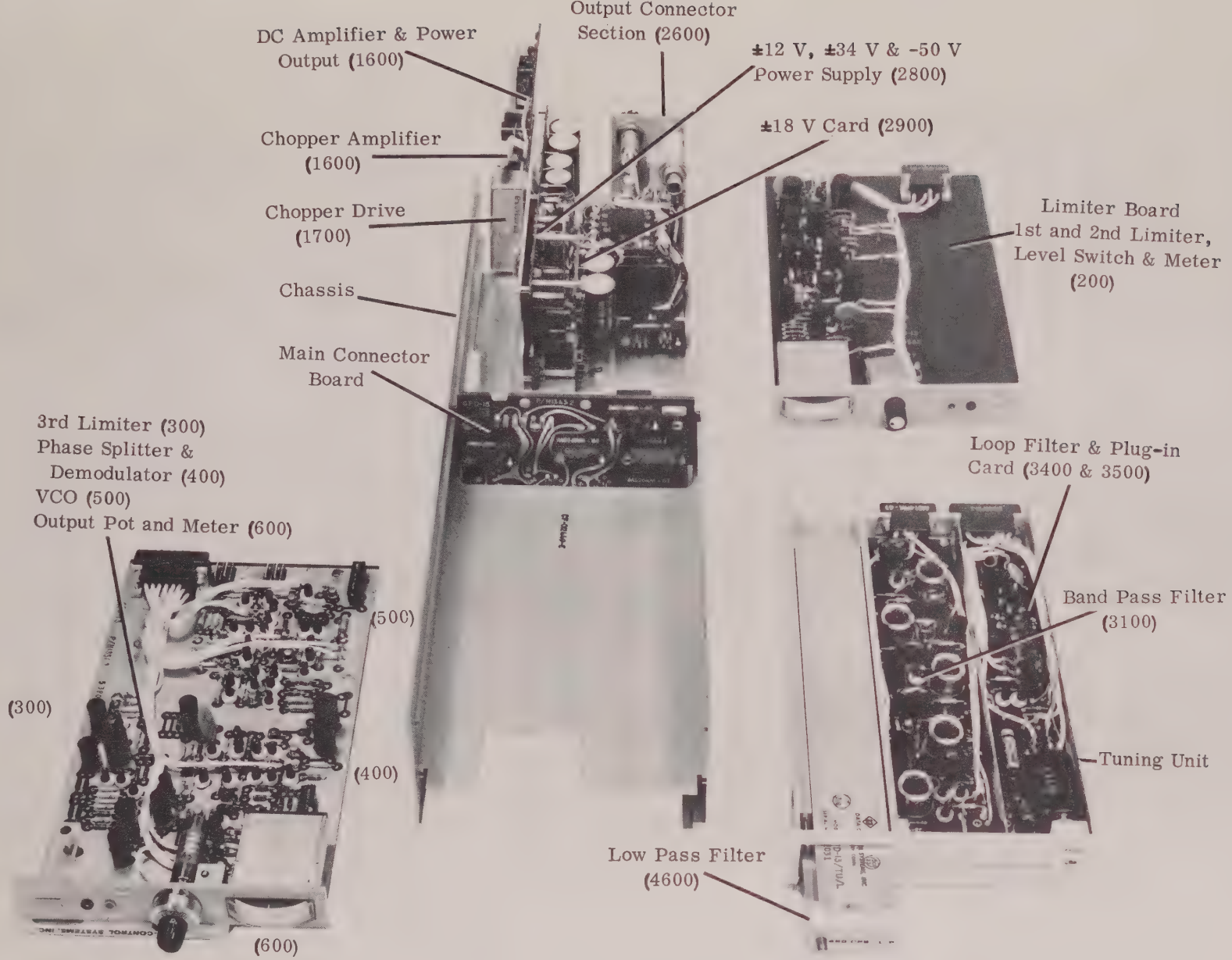


Figure 1-2A. Identification of Subassemblies

1-15. The front panel of the GFD-13 is divided into an upper and lower portion. All indicators, controls and test points associated with the input to the demodulator are on the upper panel and those associated with the output are on the lower panel.

1-16. ELECTRICAL CHARACTERISTICS. The GFD-13 employs the phase-locked loop demodulation technique in order to enhance its flexibility and range of application. The phase-locked loop demodulation technique is at least equivalent in all respects of performance to the pulse area integration technique. It provides, however, the additional capability of narrowing the demodulator noise bandwidth to increase the threshold sensitivity when handling noisy signals.

1-17. Drift Characteristics. The GFD-13 has established a new standard of performance for output stability. It utilizes no ovens, temperature controls, mechanical choppers, crystal oscillators, or other complex circuits to achieve this stability. Its circuits are designed to be inherently stable and remain so for thousands of hours of operation.

1-18. It is somewhat impractical to consider conventional drift characteristics as related to the GFD-13 because all measurable output variation is due to changes in temperature or line voltage. Line voltage and temperature coefficients have been kept extremely small and large variations in either produce only slight output zero and sensitivity changes.

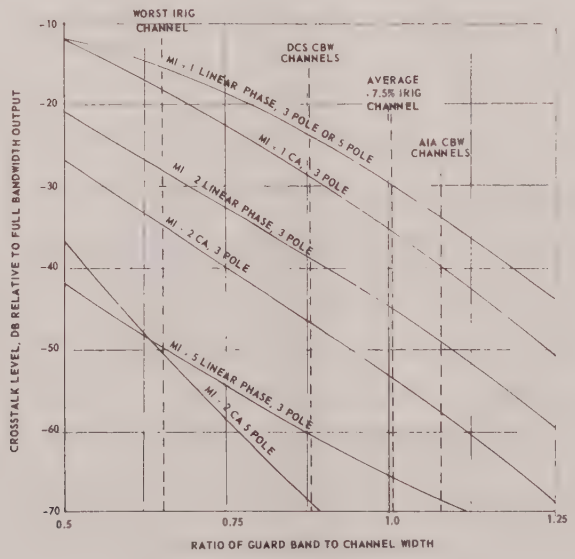
1-19. Because no oven or temperature control is used, the GFD-13 stabilizes in only a few minutes. It is not necessary to wait 30 minutes or even 15 minutes before using the demodulator.

1-20. Sensitivity. The GFD-13 achieves a sensitivity improvement on the order of 6 db to 20 db over other FM demodulators. The unit is fully quieted with an input signal of only 2 millivolts rms, and signals up to 2 volts rms are in the normal operating range. This increased sensitivity provides improved compatibility with modern, solid state magnetic tape recorders and receivers.

1-21. While tube-type electronics of the past produced multiplex levels of 10 volts rms or more, modern solid state electronics operate with typical signal levels of 1 volt rms or even 1 volt peak-to-peak. In a typical frequency multiplex, the peak-to-peak/rms ratio is very large (often 50 : 1) and it is not unusual to find individual subcarrier levels of 20 millivolts or even less where pre-emphasis has been employed. A sensitivity of 10 millivolts or even 5 millivolts provides an insufficient fade margin to contend with tape

dropouts and similar effects. No known solid state recorder or receiver manufactured today is capable of producing a multiplexed signal with individual subcarrier levels sufficient to exceed the input capabilities of the GFD-13.

1-22. Low Modulation Index Signal Handling. The GFD-13 has been optimized for operation with constant bandwidth subcarriers or special wideband subcarriers in addition to standard IRIG subcarriers. While IRIG subcarriers conventionally operate at modulation indices of 5 or more, subcarriers with modulation indices as low as one are frequently encountered with constant bandwidth and special wideband channels. Under these circumstances, conventional demodulators experience a substantial increase in distortion and interchannel crosstalk. Through a new band pass filter design technique, the GFD-13, operated at a modulation index of 2, provides distortion and crosstalk rejection characteristics comparable to other demodulators operated at a modulation index of 5. (See Figure 1-3.) The band pass filter is a multi-pole active unit with closely controlled amplitude and phase characteristics. These characteristics also enhance tape speed compensation and interchannel time correlation in low modulation index, constant bandwidth systems.



Worst case crosstalk between FM channels of equivalent amplitude with carriers located at adjacent band edges, for various modulation indices and low pass filters.

Figure 1-3. Adjacent Channel Crosstalk Characteristics

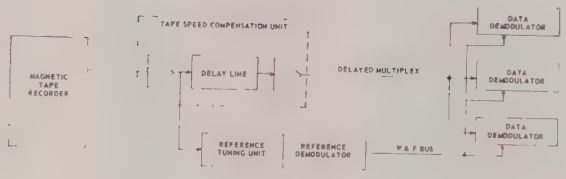
1-23. Output Amplifier. The GFD-13 output amplifier provides an exceptionally wide bandwidth in conjunction with low noise and true current limiting. It can utilize DCS low pass filters with cutoff frequencies as high as 100 kHz without a reduction in the specified output current and voltage. Output noise from the GFD-13 is exceptionally low and is specified in terms of peak-to-peak noise as well as rms noise. Peak-to-peak noise is more meaningful to the system engineer particularly when output signals are digitized for computer processing.

1-24. Most demodulator output amplifiers employ voltage limiting. This has been found to be inadequate for galvanometer protection. The GFD-13 employs true current limiting in addition to voltage limiting. Current is limited to 150% of maximum bandedge output current regardless of the output level setting.

1-25. Metering Provisions. The GFD-13 is provided with complete and accurate input/output metering. The input meter is provided with switchable full scale ranges of 20 millivolts, 200 millivolts, and 2 volts rms. A fourth switch position converts the input meter to a phase error indicator connected to the phase-locked loop. This indication is a necessary adjunct to the use of extremely narrow loop filters to achieve maximum signal/noise threshold improvement. The output meter indicates percent of bandedge deviation of the subcarrier.

1-26. Tape Speed Compensation. A great deal of simplicity and economy has been achieved in the tape speed compensation system by eliminating the need for a tape speed compensation unit and its plug-in delay line. (See Figure 1-4.) The only additional component required to obtain tape speed compensation for a system is a reference tuning unit, Model GFD-13/RTU. For changing from the use of one reference frequency to another, it is necessary to change only the reference tuning unit. Any GFD-13 FM demodulator functions as a reference demodulator when the reference tuning unit is inserted. The system is completely automatic in that it requires no phase or amplitude adjustments to achieve specified performance. A switch on the reference tuning unit permits disabling of the tape speed compensation system when desired.

1-27. Tuning Units. (See Figure 1-5.) Three types of standard tuning units are supplied to optimize the demodulator for a wide range of applications. Standard frequencies are listed in Table 1-2. The standard tuning unit, Model GFD-13/TU, is used for conventional IRIG and constant bandwidth applications with subcarrier deviation bandwidths from ±4%



Conventional Tape Speed Compensation System

Simplified Tape Speed Compensation System

Figure 1-4. Conventional and Simplified Tape Speed Compensation Systems

The low pass filter may be removed by pushbutton without removing the Tuning Unit from the Demodulator.

Figure 1-5. Tuning Unit, Model GFD-13/TU

Table 1-2. Standard Tuning Unit and Low Pass Filter Frequencies

STANDARD TUNING UNIT FREQUENCIES

	Channel	Center Freq	Deviation	Channel	Center Freq	Deviation (Percent)	Channel	Center Freq	Deviation (Percent)
IRIG FM/FM STANDARDS GFD 13/TU GFD-13/TUA	1	400 Hz	±7½%	11	7350Hz	±7½%	21	165,000 Hz	±7½%
	2	560	±7½%	12	10,500	±7½%	A	22,000	±15%
	3	730	±7½%	13	14,500	±7½%	B	30,000	±15%
	4	960	±7½%	14	22,000	±7½%	C	40,000	±15%
	5	1300	±7½%	15	30,000	±7½%	D	52,500	±15%
	6	1700	±7½%	16	40,000	±7½%	E	70,000	±15%
	7	2300	±7½%	17	52,500	±7½%	F	93,000	±15%
	8	3000	±7½%	18	70,000	±7½%	G	124,000	±15%
	9	3900	±7½%	19	93,000	±7½%	H	165,000	±15%
	10	5400	±7½%	20	124,000	±7½%			
DCS CONSTANT BANDWIDTH STANDARDS GFD-13/TU	MARK 1000	6 25 kHz	±1 kHz	MARK 2000	12 5 kHz	±2 kHz	MARK 4000	25 kHz	±4 kHz
		10 0	±1 kHz		20 0	±2 kHz		40	±4 kHz
		13 75	±1 kHz		27.5	±2 kHz		55	±4 kHz
		17 5	±1 kHz		35 0	±2 kHz		70	±4 kHz
		21 25	±1 kHz		42 5	±2 kHz		85	±4 kHz
		25 0	±1 kHz		50 0	±2 kHz		100	±4 kHz
		28 75	±1 kHz		57 5	±2 kHz		115	±4 kHz
		32 5	±1 kHz		65.0	±2 kHz		130	±4 kHz
		36 25	±1 kHz		72.5	±2 kHz		145	±4 kHz
		40 0	±1 kHz		80 0	±2 kHz		160	±4 kHz
DCS CONSTANT BANDWIDTH STANDARDS GFD 13/TU	MARK 8000	50 kHz	±8 kHz	MARK 16,000	100 kHz	±16 kHz	MARK 32,000	200 kHz	±32 kHz
		80	±8 kHz		160	±16 kHz		320	±32 kHz
		110	±8 kHz		220	±16 kHz		440	±32 kHz
		140	±8 kHz		280	±16 kHz		560	±32 kHz
		170	±8 kHz		340	±16 kHz		680	±32 kHz
		200	±8 kHz		400	±16 kHz		800	±32 kHz
		230	±8 kHz		460	±16 kHz		920	±32 kHz
		260	±8 kHz		520	±16 kHz		1040	±32 kHz
		290	±8 kHz		580	±16 kHz		1160	±32 kHz
		320	±8 kHz		640	±16 kHz		1280	±32 kHz
AIA CONSTANT BANDWIDTH STANDARDS GFD-13/TU	1 C	12.5 kHz	±2 kHz	2 CW	20 8 kHz	±4 kHz			
	2 C	20 8	±2 kHz	4 CW	37.5	±4 kHz			
	3 C	29 2	±2 kHz	6 CW	54 2	±4 kHz			
	4 C	37 5	±2 kHz	8 CW	70.8	±4 kHz			
	5 C	45 8	±2 kHz	10 CW	87.5	±4 kHz			
	6 C	54 2	±2 kHz	12 CW	104.2	±4 kHz			
	7 C	62 5	±2 kHz	14 CW	120.8	±4 kHz			
	8 C	70.8	±2 kHz	16 CW	137.5	±4 kHz			
	9 C	79.2	±2 kHz	18 CW	154.2	±4 kHz			
	10 C	87 5	±2 kHz	20 CW	170.8	±4 kHz			
	11 C	95 8	±2 kHz	22 CW	187.5	±4 kHz			
MAGNETIC RECORDING STANDARDS GFD-13/TUW		27	±40%		54 kHz 108 216	±40% ±40% ±40%			
REFERENCE FREQUENCIES GFD-13/RTU	(800 kHz, 400 kHz), 200 kHz, 100 kHz, 50 kHz, 25 kHz and 17 kHz								

STANDARD LOW PASS FILTER FREQUENCIES

	Band	MI-5 Freq. (Hz)	MI-1 Freq. (Hz)	Band	MI-5 Freq. (Hz)	MI-1 Freq. (Hz)	Band	MI-5 Freq. (Hz)	MI-1 Freq. (Hz)
IRIG FM/FM STANDARDS GFD-13/TU/L GFD 13/TU/LSM	1	6	30	11	110	550	21	2500	12,500
	2	8 4	42	12	160	800	A	660	3300
	3	11	55	13	220	1100	B	900	4500
	4	14	70	14	330	1650	C	1200	6000
	5	20	100	15	450	2250	D	1600	8000
	6	25	150	16	600	3000	E	2100	10,500
	7	35	175	17	790	3950	F	2800	14,000
	8	45	225	18	1050	5250	G	3700	18,500
	9	59	295	19	1400	7000	H	5000	25,000
	10	81	405	20	1900	9500			

CONSTANT BANDWIDTH AND OTHERS GFD-13/TU/L GFD-13/TU/LSM					
	250 Hz	2000	5000	16,000	40,000
	500	2500	8000	20,000	50,000
	1000	4000	10,000	25,000	

Standard Frequencies and Deviations

to ±25%. The loop filter has a cutoff frequency corresponding to a modulation index of 1 for the channel, so that a full deviation step function will not cause loss of lock. For channels with deviation bandwidths from ±25% to ±40%, the wide deviation tuning unit, Model GFD-13/TUW, is utilized. It, too, is provided with a modulation index of 1 loop filter. Only a rudimentary band pass filter is included unless otherwise specified. The GFD-13/TUA is an adjustable loop filter tuning unit of the type pioneered by DCS. It provides six switch selectable loop filters having noise bandwidths of 100%, 75%, 50%, 30%, 15%, and 7% of the channel bandwidth. The unit also includes a loop "phase error" control which permits optimizing S/N threshold and noise immunity regardless of the subcarrier location within the band. The control is used in conjunction with the input meter when it is switched to its "phase error" position. This control is necessary for all true phase-locked loop demodulators whose loops can be narrowed sufficiently to achieve significant threshold improvement. Model GFD-13/TUR is a special tuning unit for optimum demodulation at the 70 kHz subcarrier frequency with ±30% deviation. It is typically multiplexed with other channels including adjacent channel 15 and is modulated by a 3600 pps PAM signal. This unit has very high crosstalk rejection with outstanding transient characteristics of the output waveform.

1-28. Low Pass Filters. The standard low pass filter, Model GFD-13/TU/L, is available with either constant amplitude (Butterworth) or linear phase (constant delay) response characteristics. Both types of filters are available in three- or five-pole configurations. The GFD-13/TU/LSM is a switchable mode low pass filter which permits the selection of either the linear phase or constant amplitude response characteristic. This unit is available only in the three-pole configuration.

1-29. HOUSING. The GMH-13 housing mounts three FM demodulators side by side in 3-1/2 inches of panel space. It provides all electrical connections to the GFD-13 permitting removal from the housing without disturbing system wiring. All demodulator signal input and output connections are BNC and power is applied to the housing via a single connector. The housing also provides RFI shielding and line filtering.

1-30. PERFORMANCE CHARACTERISTICS. Due to the great flexibility of the GFD-13 and the variety of plug-in units available, it is not feasible to describe its performance capabilities in all possible applications and configurations. DCS, therefore, specifies a maximum operating range and a normal operating range for the GFD-13. The normal operating range

relates most directly to conventional IRIG and Constant Bandwidth system usage. Where performance characteristics vary with modulation index, specifications are stated for various modulation indices. When considering applications which exceed the normal operating range, DCS should be consulted regarding individual performance parameters.

Maximum Operating Range

Input Subcarrier Frequencies:	300 Hz to 1 mHz
Subcarrier Dev.:	±2% to ±40%
Output Frequency Response:	DC to 100 kHz

*Normal Operating Range

Input Subcarrier Frequencies:	300 Hz to 300 kHz
Subcarrier Dev.:	±4% to ±16%
Input Impedance:	500,000 ohms minimum shunted by 50 pf maximum
Input Subcarrier Level:	2 millivolts to 2 volts rms
Input Selectivity:	With a standard tuning unit, a subcarrier located at three times the normal channel deviation will be attenuated at least 28 db as measured at the band pass filter output
AM Rejection:	Less than 0.3% of full bandwidth peak transient for a 20 db change in subcarrier level at center frequency, with a channel modulation index of 5 or greater
Static Non-Linearity:	Less than .05% of full bandwidth independent
Harmonic Distortion:	Less than 1% of full bandwidth for all frequencies, with a channel modulation index of 2. Less than 0.3% of full bandwidth for all frequencies, with a channel modulation index of 5
Output Zero Stability:	Less than 0.0075%/°C of center frequency after a 10 minute warmup.
Output Sensitivity Stability:	Less than 0.0025%/°C of center frequency after a 10 minute warmup.

*Normal operating specifications apply when using a standard 3-pole Butterworth Filter in combination with a low pass filter corresponding to an M.I. of 5 unless otherwise stated.

Line Voltage Sensitivity:	Less than ±0.1% of full bandwidth change in zero or sensitivity for a 10 volt change in line voltage.
Output Frequency Response:	DC to 100 kHz
Output Voltage:	Continuously adjustable from ±1 volt to ±10 volts for full bandwidth deviation. NOTE: A nine-turn Vernier output control is available to order.
Output Polarity:	An increasing frequency produces a positive-going voltage. (A reversing polarity option is available.)
Output Current:	±100 ma for full bandwidth deviation.
Output Impedance:	Less than 0.1 ohm.
Output Noise:	Less than 5 mv rms for an input of 2 mv rms and a channel modulation index of 5 or greater. Less than 3 mv rms and 20 mv peak-to-peak for inputs between 10 mv and 2 V rms and a channel modulation index of 5 or greater.
Output Limiter:	Current is limited to ±150 ma for any setting of output level control. An external load to dissipate a portion of the output current can be used to provide precise galvanometer protection.
Output Capacitive Loading:	0.01 ufd at any setting of output level control.
Tape Speed Compensation:	30 db minimum attenuation of flutter frequencies up to channel modulation indices of 5 or greater. Attenuation is achieved with subcarriers located anywhere within their bands.
Power Required:	105 to 125 volts rms, 55 to 65 Hz, 15 watts maximum per unit.
Operating Temperature Range:	0°C to 60°C with circulating air.

Front Panel Controls and Indicators

Input meter, 4 ranges:	20 MV, 200 MV, and 2 volts rms full scale. Fourth range indicates loop phase error.
Input meter switch:	4 position.
Output meter:	±5% of bandedge deviation from band center.
Output level control:	9 turn.
Power switch:	Lighted pushbutton

Lock Loss Indicator light

Input Test Point (output of band pass filter)

Output Test Point

Ground Test Point

Dimensions	3.44" high x 5.8" wide x 18.5" long. Three units mount side by side in Model GMH-13 Housing which occupies 3-1/2 inches of panel space in standard 19 inch wide relay rack.
Weight	10 pounds maximum.
Front Panel Color	Blue per FED-STD-595.
Chassis Finish	Yellow Chromate.
Ordering Information	Specify FM Subcarrier Demodulator, Model GFD-13.

Model GFD-13/TU Standard Tuning Unit

Channel Frequencies:	300 Hz to 300 kHz for normal operation. Channel frequencies as high as 1 mHz can be supplied for special applications.
Channel Dev.:	±4% to ±16% for normal operation. Channel deviations from ±2% to ±25% can be supplied for special applications.
Attenuation:	Less than 3 db at bandedges. More than 28 db at three times the normal channel deviation.
Loop Filter Response:	Loop filter cutoff frequency corresponds to a modulation index of 1 for the channel to accommodate a full bandwidth step function without loss of lock.

Tape Speed Compensation:	All necessary networks for Tape Speed Compensation are included.
Controls:	Zero Adjustment.
Weight:	2.5 pounds maximum.
Front Panel Color:	White per FED-STD-595.
Chassis Finish:	Yellow Chromate.
Ordering Information:	Specify Standard Tuning Unit, Model GFD-13/TU (frequency and deviation). Example: GFD-13/TU (70 kHz±7.5%)

Model GFD-13/TUW Wide Deviation Tuning Unit

Channel Frequencies:	300 Hz to 300 kHz for normal operation.
Channel Dev.:	±16% to ±40%.
Attenuation:	Less than 3 db at bandedges. A rudimentary filter provides only slight out-of-band attenuation.
Loop Filter Response:	Loop filter cutoff frequency corresponds to a modulation index of 1 for the channel to accommodate a full bandwidth step function without loss of lock.
Tape Speed Compensation:	Necessary networks for Tape Speed Compensation are included in all channels with 30% deviation or less. Above 30% deviations, networks are included in frequencies from 25 kHz to 300 kHz.
Controls:	Zero Adjustment.
Weight:	2.5 pounds maximum.
Front Panel Color:	White per FED-STD-595.
Chassis Finish:	Yellow Chromate.
Ordering Information:	Specify Wide Deviation Tuning Unit, Model GFD-13/TUW (frequency and deviation). Example: GFD-13/TUW (200 kHz ±40 kHz)

Model GFD-13/TUA Adjustable Loop Filter Tuning Unit (see Figure 1-6)

Channel Frequencies:	1000 Hz to 300 kHz for normal operation. Channel frequencies from 400 Hz to 1 mHz can be supplied for special applications.

Combined response of bandpass and loop filters in GFD-13 for various demodulation noise bandwidths (switch-selectable in GFD-13/TUA Adjustable Loop Filter Tuning Unit).

Figure 1-6. Combined Response of Band Pass and Loop Filters in GFD-13 for various demodulation noise bandwidths (switch-selectable in GFD-13/TUA Adjustable Loop Filter Tuning Unit)

Table 1-3. Maximum Intelligence Capacity of the Standard IRIG channels for various GFD-13 Demodulator Noise Bandwidths

Demodulation Noise Bandwidths		100%	75%	50%	30%	15%	7%
Maximum Intelligence Frequency (Hz) for Full Bandwidth Deviation	IRIG BAND 1	30	7.5	1.20	.300	.075	.012
	2	42	10.5	1.68	.420	.105	.017
	3	55	13.75	2.20	.550	.1375	.022
	4	70	17.5	2.80	.700	.175	.028
	5	100	25.0	4.00	1.00	.250	.040
	6	125	31.25	5.00	1.25	.3125	.050
	7	175	43.75	7.00	1.75	.4375	.070
	8	225	56.25	9.00	2.25	.5625	.090
	9	295	73.75	11.8	2.95	.7375	.118
	10	405	101.25	16.2	4.05	1.012	.162
	11	550	137.5	22.0	5.50	1.375	.220
	12	800	200.0	32.0	8.00	2.00	.320
	13	1100	275.0	44.0	11.00	2.75	.440
	14	1650	412.0	66.0	16.50	4.12	.660
	15	2250	562.5	90.0	22.50	5.62	.900
	16	3000	750.0	120.0	30.00	7.50	1.20
	17	3950	987.5	158.0	39.50	9.87	1.58
	18	5250	1312.5	210.0	52.50	13.12	2.10
	A	3300	825.0	132.0	33.00	8.25	1.32
	B	4500	1125.0	180.0	45.00	11.25	1.80
	C	6000	1500.0	240.0	60.00	15.0	2.40
	D	8000	2000.0	320.0	80.00	20.0	3.20
	E	10500	2625.0	420.0	105.00	26.25	4.20

Channel Dev.:	±4% to ±16% for normal operation. Deviations from ±2% to ±25% can be supplied for special applications.
Attenuation:	Less than 3 db at bandedges. More than 28 db at three times the normal channel deviation.
Loop Filters:	Six loop filters providing demodulator noise bandwidths of 100%, 75%, 50%, 30%, 15%, and 7% of channel bandwidth.
Loop Filter Switching:	Non-interruptive. Lock is maintained during switch operation.
S/N Threshold Improvement:	10 db for 7% noise bandwidth loop.
Tape Speed Compensation:	All necessary networks for Tape Speed Compensation are included.
Controls:	Loop Filter Switch, six positions, Phase Adjustment, Zero Adjustment.
Weight:	2.5 pounds maximum.
Front Panel Color:	White per FED-STD-595.
Chassis Finish:	Yellow Chromate.
Ordering Information:	Specify Adjustable Loop Filter Tuning Unit, Model GFD-13/TUA (frequency and deviation). Example: GFD-13/TUA (40 kHz ±15%)

Model GFD-13/RTU Reference Tuning Unit

Reference Frequencies:	Reference frequencies up to 300 kHz can be accommodated for normal operation. Standard frequencies are 17 kHz, 25 kHz, 50 kHz, 100 kHz and 200 kHz.
Frequency Dev.:	Specified compensation is achieved for tape speed variations of ±3% maximum.
Controls:	Zero Adjustment, Tape Speed Compensation ON-OFF Switch.
Weight:	4 pounds maximum.

Front Panel Color:	White per FED-STD-595.
Chassis Finish:	Yellow Chromate.
Ordering Information:	Specify Reference Tuning Unit, Model GFD-13/RTU (reference frequency). Sample: GFD-13/RTU (100 kHz)

Model GFD-13/TU/L Standard Low Pass Filter (see Figure 1-7)

The following specifications apply to the standard three-pole filter configuration utilized in normal applications.

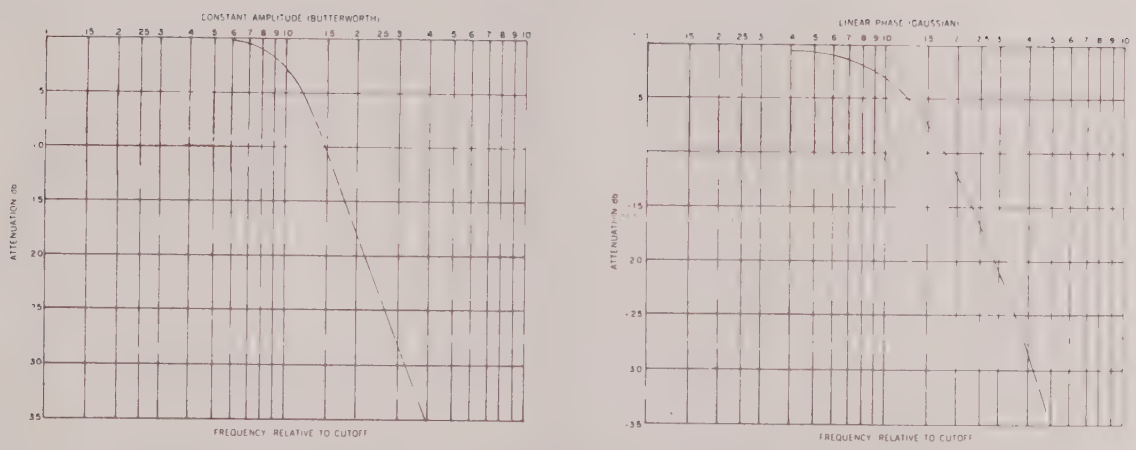
Cutoff Frequencies:	6 Hz to 100 kHz.
Response Characteristics:	Constant Amplitude and Linear Phase are standard.

Constant Amplitude Characteristics

Amplitude Response:	Cutoff defined as -3 db ±.5 db point. Down 18 db at two times cutoff frequency.
Slope:	18 db per octave.
Overshoot:	15% maximum.

Linear Phase Characteristics

Amplitude Response:	Cutoff defined as -3 db ±.5 db point. Down at least 11 db at two times cutoff frequency.
Slope:	Asymptotic to 18 db per octave.
Overshoot:	1.5% maximum.
Controls:	None
Weight:	One pound maximum.
Front Panel Color:	White per FED-STD-595.
Chassis Finish:	Yellow Chromate.
Ordering Information:	Specify Standard Low Pass Filter, Model GFD-13/TU/L (frequency and characteristic). LP and CA are used to indicate Linear Phase and Constant Amplitude characteristics respectively. Example: GFD-13/TU/L (10.5kHz CA)



Characteristics of Constant Amplitude and Linear Phase GFD-13/TU/L Standard Low Pass Filters.

Figure 1-7. Characteristics of Constant Amplitude and Linear Phase GFD-13/TU/L Standard Low Pass Filters

Model GFD-13/TU/LSM Switchable Low Pass Filter (see Figure 1-8)

Cutoff Frequencies:	6 Hz to 100 kHz.
Response Characteristics:	Constant Amplitude and Linear Phase responses are available by front panel selector switch.

Constant Amplitude Characteristics

Amplitude Response:	Cutoff is defined as 0.5 db ±0.5 db point. Down 6.5 db ±1.5 db at two times cutoff frequency.
Slope:	18 db per octave.
Overshoot:	15% maximum.

Linear Phase Characteristics

Amplitude Response:	Cutoff defined as -3 db ±.5 db point. Down at least 10 db at two times cutoff frequency.
Slope:	Asymptotic to 18 db per octave.
Overshoot:	1.5% maximum.
Controls:	Selector switch, 2 position. Constant Amplitude or Linear Phase.
Weight:	One pound maximum.
Front Panel Color:	White per FED-STD-595.
Chassis Finish:	Yellow Chromate.
Ordering Information:	Specify Switchable Low Pass Filter, Model GFD-13/TU/LSM (frequency). Example: GFD-13/TU/LSM (660 Hz)

Figure 1-8. Characteristics of Constant Amplitude and Linear Phase GFD-13/TU/LSM Standard Switchable Low Pass Filters

SECTION II

INSTALLATION

2-1. GENERAL.

2-2. This section describes initital instruction and the electrical connections required for a Data or Reference Demodulator. The scope of this information covers functional installation and precludes operation of the unit.

2-3. UNPACKING AND HANDLING.

2-4. The equipment is sealed in a moisture proof polyethelene blister-pack assembly and insulated from shock during shipment with polyurethane foam packing material.

2-5. Remove the corrugated carton and protective covering and perform a general visual inspection. Inspect for physical signs of damage such as broken indicators and controls on the front panel and damage to the case. Retain the carton and protective covering until inspection is completed.

2-6. MOUNTING.

2-7. The FM Demodulator is housed in a GMH-13 Modular Housing Assembly which, in turn, may be placed in a standard 19" rack. The housing assembly accommodates three demodulators side by side in 3.5 inches of panel height, 19-3/4 inches deep, and provides all signal and power connections.

2-8. The Emcor enclosure is particularly suitable since vertical angle iron supports are supplied. On each side of the enclosure an aluminum angle support is mounted horizontally, parallel to the rack side panels, and fastened to the vertical angle iron supports. Two types of angle supports are available for fastening to vertical iron supports; one with an ear, one without. (See Figure 2-1.)

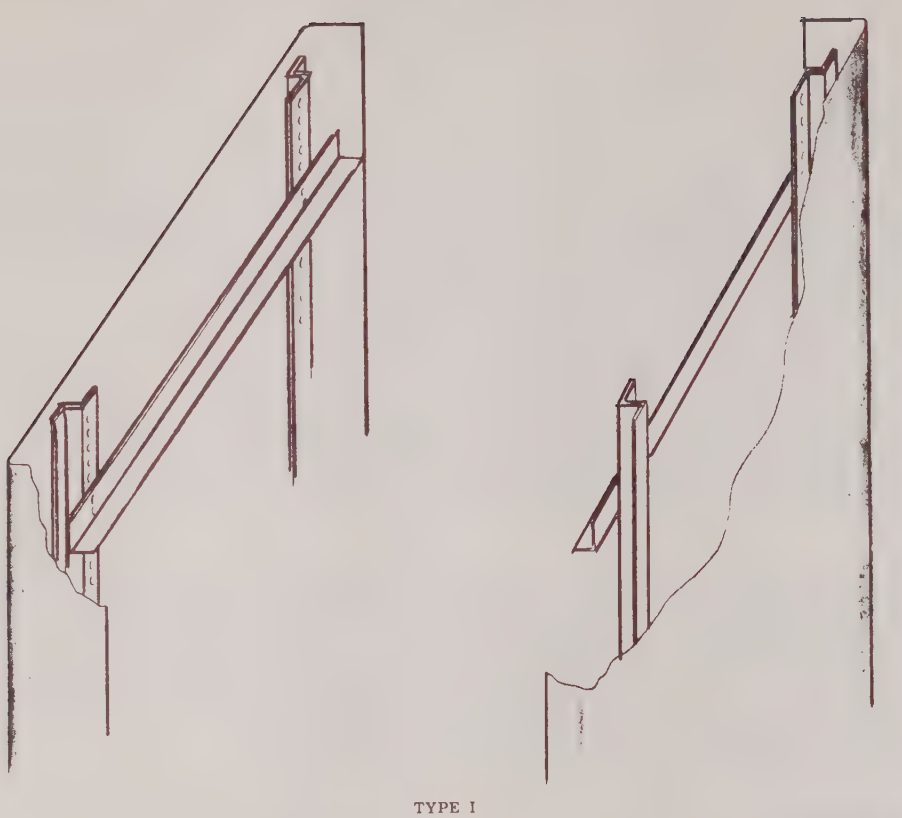
2-9. The housing slides in the front of the enclosure and rests upon the aluminum angles. Two tabs at the rear of the housing are fastened to the aluminum angles with screws. Two panel screws fasten the housing panel to the front of the enclosure.

NOTE

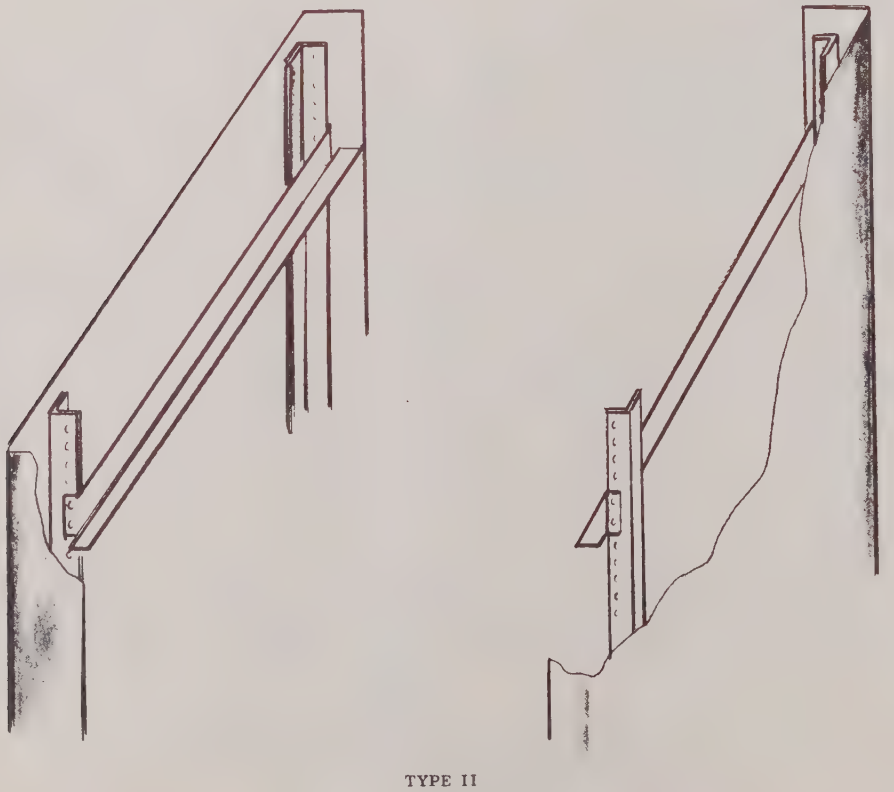
Panel mounting without angle support is not recommended.

2-10. COOLING.

2-11. An adequate supply of cooling air must be provided to maintain temperature



TYPE I



TYPE II

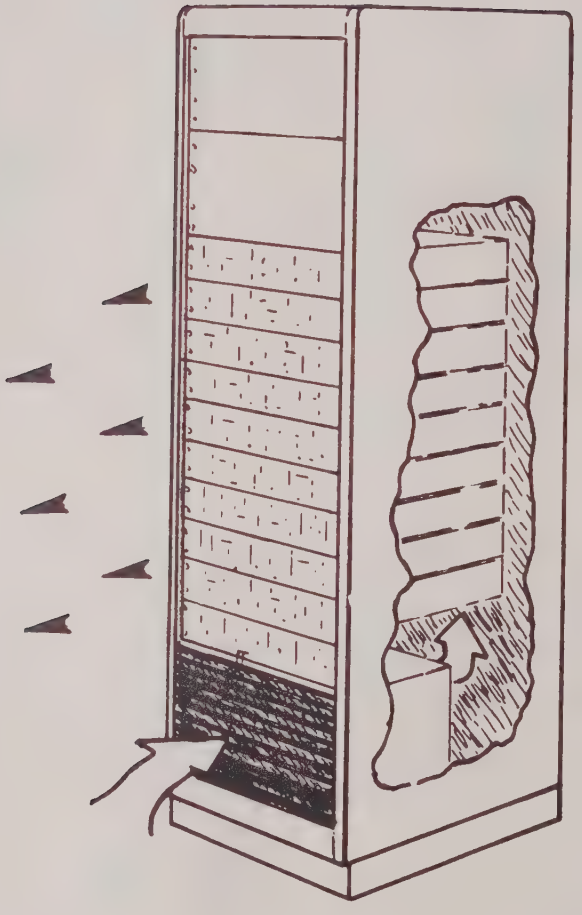
Figure 2-1. Mounting Angles, Type I and Type II

stability (see Figure 2-2). Do not install the GFD-13 in an enclosure containing equipment which dissipates an excessive amount of heat.

2-12. CONNECTORS. The input-output and power connector at the rear of the GFD-13 Demodulator is a Burndy MS-26PM-61 and mates with Burndy MS-26RM-61 which is located in the GMH-13 Modular Housing Assembly. The assembly of male and female contacts which make up these connectors is shown in Figure 2-3. The function of each connector terminal with connections required for normal operation as a data demodulator or a reference demodulator is listed in Tables 2-1 and 2-2.

2-13. A data demodulator may be changed to a reference demodulator by changing its tuning unit. No internal wiring need be changed since the connector pin functions are compensated for by rewiring within the tuning unit. Either a data or a reference demodulator may be inserted in any position of the GMH-13 Modular Housing, however, it must be remembered that the functions of the rear BNC connectors change as listed in Table 2-3. Figure 2-3 illustrates the location of BNC connectors at the rear of the GMH-13 Housing Assembly.

2-14. If the VCO output is required from the reference demodulator for translation or other applications, a GFD-13/RTUC tuning unit must be inserted into the demodulator. This tuning unit has no delay line as the delay line is located in the GFT-6 Frequency Translators. A T-connector is used at the input if the reference signal is recorded with the multiplex. If multiplex and reference signal are separate inputs, eliminate the T-connector and feed the Multiplex directly to an external delay. J103 is the VCO output.



Air flow is 40 cfm per GMH-13. Installation shall be semi-pressurized to approximately 0.2 in. of water to permit cooling by air flow over and around units.

Figure 2-2. Typical Example of Rack Cooling

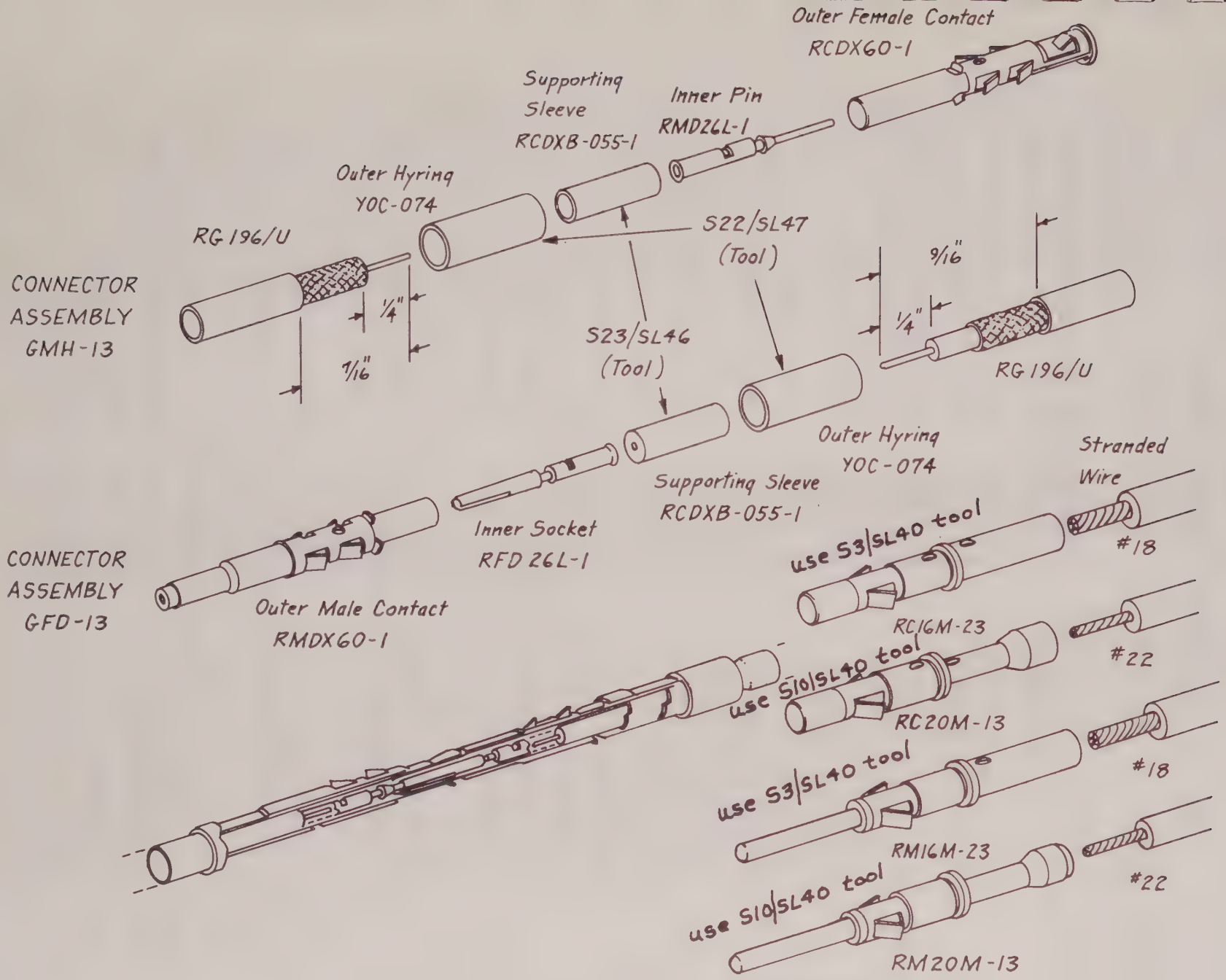


Figure 2-3. Assembly of Male and Female Contacts

Table 2-1. Data Demodulator Housing Connections

Subcarrier Input
Voltage Output
VCO Monitor
External Zero Offset
Wow and Flutter Input (when this input is not used it should be terminated with a shorted BNC connector on the rear of the housing)

P1 Plug (Demodulator)		S1 Socket (Housing)	
Pin No.	Pin Connections	Pin No.	Pin Connections
A	Output	A	Output
B	Subcarrier Monitor	B	
C	Output Ground	C	Output Ground
D	Subcarrier Input	D	Subcarrier Input
E	Auto-Cal	E	
F	VCO Output	F	VCO Output
H	Feedback #1	H	Jumper to M & P
J	W & F Input	J	W & F Input
K	Auto-Cal	K	
L	Current Out (+)	L	Jumper to R
M	Feedback #2	M	Jumper to H & P
N	Ext. Zero	N	Ext. Zero Offset (shorted BNC on GMH-13)
P	Feedback	P	Jumper to M & H
R	Current Out (-)	R	Jumper to L
S ↓ AA	No Connection	S ↓ AA	No Connection
BB	AC Line	BB	115 VAC Input
CC	No Connection	CC	
DD	AC Line	DD	115 VAC Input

DATA DEMODULATOR CONNECTOR CONTACTS

A. OUTPUT.

Normal voltage output of ±10 volts maximum for a bandedge signal input.

B. SUBCARRIER MONITOR.

Output of the band pass filter of the demodulator.

C. Output Ground.

D. Subcarrier Input.

E. Auto-Cal.

Used for external sensitivity adjustment (Figure 2-4).

F. VCO Output.

The VCO output is a square wave from -5 volts to -15 volts at the subcarrier frequency.

H. Feedback #1.

Used in conjunction with contacts M & P in selecting between internal sensitivity adjust and external sensitivity adjustment. This external sensitivity adjustment can be used in an automatic calibration adjustment system.

J. Wow and Flutter.

This is the input to the Data Demodulator VCO. When no wow and flutter input is desired, a shorted cable should be put on the RG-196/U cable output. The input resistance of the wow and flutter input is 5,000 ohms nominal. With a +1.414 peak volts on this contact the demodulator deviates one percent of center frequency lower.

K. Auto-Cal.

Used for external sensitivity adjustment and will be discussed in a later paragraph of this section titled CONNECTIONS FOR EXTERNAL SENSITIVITY ADJUSTMENT.

L. Current Output (+).

Used in conjunction with contact R to obtain a demodulator current output. Discussed in a later paragraph of this section titled CONNECTIONS FOR CURRENT OUTPUT.

M. Feedback #2.

Used in conjunction with contact H and contact P in selecting between internal sensitivity adjustment and external sensitivity adjustment. This external sensitivity adjustment can be used in an automatic calibration adjustment system.

N. External Zero.

The external zero is an input whose function is to offset the DC component of the output intelligence. This offset should be introduced with a DC voltage. The sensitivity of this input is 12.5 millivolts per percent of bandwidth and the sense is negative. Thus, if the bandedge voltage is set for maximum (±10 volts), the output from the demodulator will be -2 volts DC when an input of +2.5 volts DC is put on the contact N. The above case is with a center frequency signal into the demodulator.

The input resistance of this contact is greater than 100,000 ohms. This input can also be used for zero adjustment in an automatic calibration system. If this input is not used, it should be grounded with a shorted coax cable, RG-196/U.

P. Feedback.

Used in conjunction with contacts H & M to select between internal and external sensitivity adjustment. This external sensitivity adjustment can be used in an automatic calibration adjustment system.

R. Current Output (-).

Used in conjunction with contact L to obtain a demodulator current output and will be discussed in a later paragraph of this section titled CONNECTIONS FOR CURRENT OUTPUT.

S thru AA. No Connection.

BB. Power.

One side of the power line input.

CC. No Connection.

DD. Power.

One side of the power line input.

Table 2-2. Reference Demodulator Housing Connections

Multiplex Input
Delayed Multiplex Output
Tape Speed Compensation Signal Input
Tape Speed Compensation Signal Output
Wow and Flutter Input should be terminated with a shorted BNC

P1 Plug (Demodulator)		S1 Socket (Housing)	
Pin No.	Pin Connections	Pin No.	Pin Connections
A	Output, Tape Speed Compensation Signal	A	Output, Tape Speed Compensation Signal
B	Subcarrier Monitor	B	
C	Output Ground	C	Output Ground
D	Input, Tape Speed Compensation Signal	D	Input, Tape Speed Compensation Signal
E	Auto-Cal	E	
F	Input, Multiplex	F	Input Multiplex
H	Feedback #1	H	Jumper to M & P
J	W & F Input	J	W & F Input (shorted BNC on GMH-13)
K	Auto-Cal	K	
L	Current Out (+)	L	Jumper to R
M	Feedback #2	M	Jumper to H & P
N	Output, Delayed Multiplex	N	Output, Delayed Multiplex
P	Feedback	P	Jumper to M & H
R	Current Out (-)	R	Jumper to L
S ↓ AA	No Connection	S ↓ AA	No Connection
BB	AC Line	BB	115 VAC Input
CC	No Connection	CC	
DD	AC Line	DD	115 VAC Input

REFERENCE DEMODULATOR - CONNECTOR CONTACT DESCRIPTION

Same as Data Demodulator with the following exceptions:

A. Tape Speed Compensation Signal Output.

Output of the Reference Demodulator which is proportional to the Wow and Flutter caused by the tape recorder and is fed to the Wow and Flutter bus of the Data Demodulators.

D. Tape Speed Compensation Signal Input.

Reference frequency input.

F. Multiplex Input.

Input to the delay line amplifier. It is the multiplex signal fron. e recorder.

N. Delayed Multiplex Output.

Output of the delay line amplifier. It is the delayed multiplex signal that is fed to the Data Demodulators.

NOTE

When the GFD-13 is used as a Reference Demodulator the GAIN potentiometer must be turned fully clockwise in order to get a true reading on the output meter in respect to output volts.

Table 2-3. Signal Interconnection

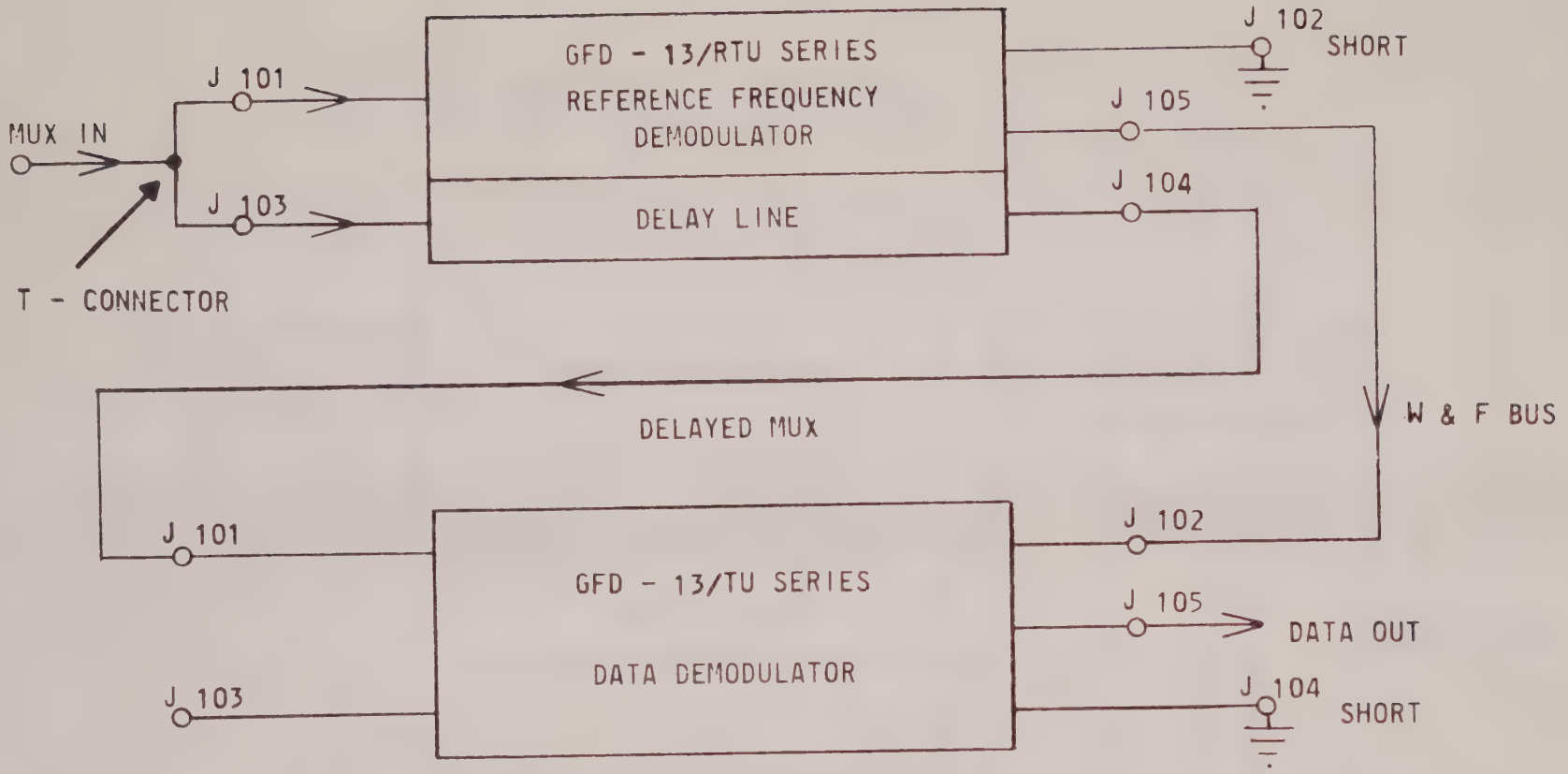
Number	Connector	Mating Connector	Number	Function	
				Data Demodulator	Reference Demodulator
J101*	Dage 30728-1	UG-88C/U	P101	Input	Input, reference frequency signal
J102	Dage 30728-1	UG-88C/U	P102	Wow & Flutter Input	Wow & Flutter input (shorted BNC on GMH-13)
J103	Dage 30728-1	UG-88C/U	P103	VCO Output	Multiplex Input
J104	Dage 30728-1	UG-88C/U	P104	External zero offset (shorted BNC)	Delayed Multiplex Output to J101 of Data Demodulator
J105	Dage 30731-1	UG-88C/U	P105	Output	Output, tape speed compensation signal to J102 of Data Demodulator

*When the reference frequency is in the multiplex a T-connector must be used at J101.

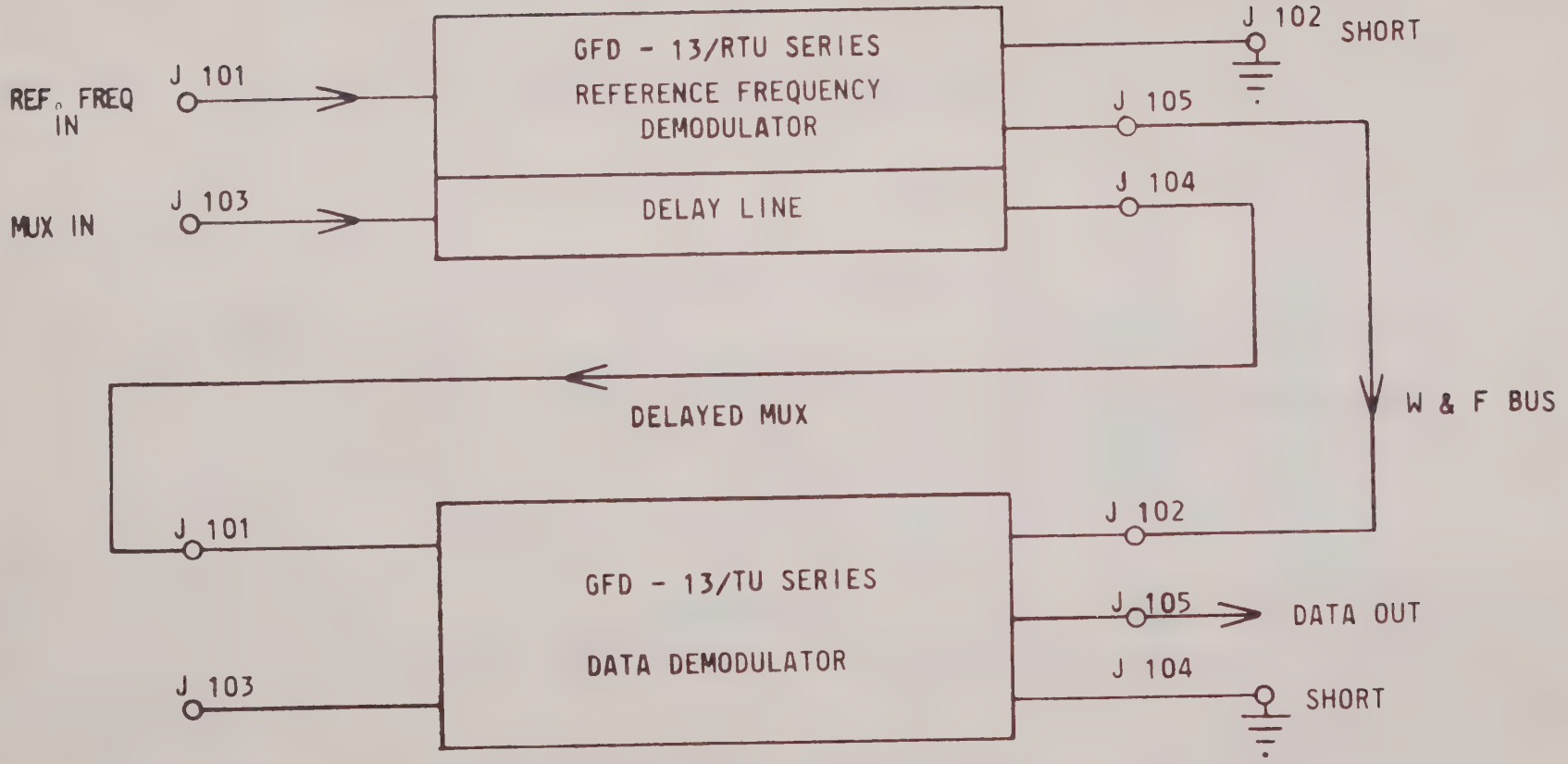
2-15. GMH-13 SIGNAL INTERCONNECTIONS: TAPE SPEED COMPENSATION.

2-16. When using the GFD-13/RTU for Tape Speed Compensation, signals must be interconnected differently when the reference frequency is contained on the MUX track and when the reference frequency is on a separate track. The interconnections are shown in the diagrams.

2-17. If the reference frequency is on the same track as the data MUX, a T-Connector is required to parallel J101 and J103 on the GFD-13/RTU.



REFERENCE FREQUENCY ON MUX TRACK



REFERENCE FREQUENCY ON SEPARATE TRACK

SECTION III

OPERATION

3-1. GENERAL.

3-2. The section describes initial operating procedures and operating instructions for the Model GFD-13 Demodulator. It is assumed that the equipment is set up in accordance with Section II.

3-3. OPERATING INSTRUCTIONS.

a. Insert the GFD-13 into the housing assembly and connect cables at the rear of the GMH-13 in accordance with Table 2-3, Section II.

b. Insert the tuning unit corresponding to the channel or reference frequency desired into the demodulator.

c. Insert the low pass filter which corresponds to the proper frequency and modulation index into the low pass filter.

d. Depress the POWER switch and allow a 10 minute warmup.

e. Connect a frequency source to GMH-13 housing assembly BNC input connector(s).

f. Adjust the frequency source to the tuning unit center frequency designated on the front panel of the tuning unit.

g. Set the voltage level of the frequency source between 2 mv and 2 volts rms. The level of the incoming signal may be determined by changing the position of the INput level range switch until the INput meter reads on scale. Full scale meter readings are 20 mv, 200 mv and 2 volts rms.

h. Adjust the band centering screwdriver control on the tuning unit marked ZERO until the OUTput meter reads center scale.

i. Change the incoming signal to the channel low bandedge frequency. The OUTput meter will indicate low bandedge (left full scale). If the tuning unit has an output polarity control on the front panel, the OUTput meter may read high bandedge. The polarity control must be set in the proper position.

j. Adjust the OUTput level control of the demodulator and monitor output jack J105 at the rear of the housing or the front panel jack marked OUT located on the lower panel of the unit.

k. Connect the input to the signal to be measured and the output to the display or recording unit. The demodulator is ready for operation.

3-4. TUNING UNIT AND LOW PASS FILTER. Selection of the desired subcarrier frequency is accomplished by installing the appropriate Model GFD-13/TU tuning unit in the demodulator. A locking lever is located beneath the tuning unit space on the front panel of the demodulator with Data-Control Systems, Inc. printed on its surface. The tuning unit may be extracted by pulling gently forward on the handle. When the tuning unit is relocated the handle automatically assumes a position wherein it can be pushed in flush with the tuning unit. This engages the tuning unit and locks it securely in place. The handle also functions to lock the demodulator into its housing. When the handle is pulled forward to extract the tuning unit, the demodulator can also be pulled out of its housing.

When a standard tuning unit is used an increase in frequency at the input will cause a corresponding increase in output voltage. Tuning units suffixed by designations D and E may be used for reverse polarity switching, manual operation and remote/manual operation, respectively.

Where front panel input level switches are used on the tuning unit the x1 or x5 switch must be multiplied times the demodulator input level setting to arrive at the full scale value for the meter. For example, if the desired input level is 10 V, the toggle switch on the tuning unit is placed in the x5 position which attenuates the input 1/5. For a full scale reading on the meter, the demodulator front panel input level switch must be set at 2 V (2V x 5 = 10 V input).

3-5. The low pass filter plugs into the front of the tuning unit so that it can be replaced without removing the tuning unit, and is removed by pushing a small button on its front panel. When the tuning unit is removed, the low pass filter remains locked into it, but may be removed by activating the pushbutton.

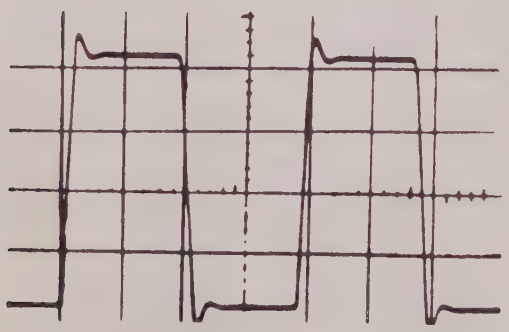
3-6. CHOICE OF LOW PASS FILTER. Two types of GFD-13/TU/L, low pass filters, are available. These are (1) the constant amplitude (Butterworth) and (2) the linear phase (Gaussian) types.

3-7. The constant amplitude filter maintains a relatively flat amplitude characteristic from low frequencies almost to the cutoff frequency. The linear phase filter amplitude

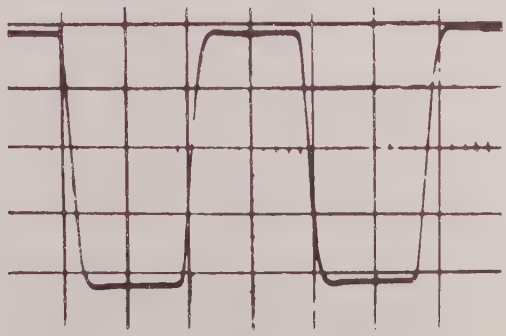
characteristic falls of gradually as its cutoff frequency is approached. Figure 3-1 compares the amplitude characteristics of the two types. A characteristic of the linear phase filter is that its phase shift increases linearly with frequency. Figure 3-2 compares the phase characteristics of the two types.

3-8. If the data is sinusoidal and its amplitude is important, especially up to the vicinity of filter cutoff, the constant amplitude type should be used. This affords accurate amplitude measurement over the entire data bandwidth, and the sharper cutoff yields a higher data signal-to-noise ratio.

3-9. When the data is represented by a square wave or other transient form containing several frequency components, the phase relationship between the frequency components may be more important to maintain than the amplitude relationship. When the square wave is applied to a constant amplitude filter, its phase distortion misplaces the individual component frequencies so that the output may contain one or more overshoots. In this case the linear phase filter may be more appropriate because it does not introduce phase distortion and hence, its output will not contain large overshoots. The output will be a faithful representation of the input square wave, limited only by the filter rise times. Figure 3-3 illustrates demodulator response to a step function change in subcarrier frequency with both types of filters.



Constant Amplitude



Linear Phase

Figure 3-3. Step Function Response of Linear Phase and Constant Amplitude Low Pass Output Filters

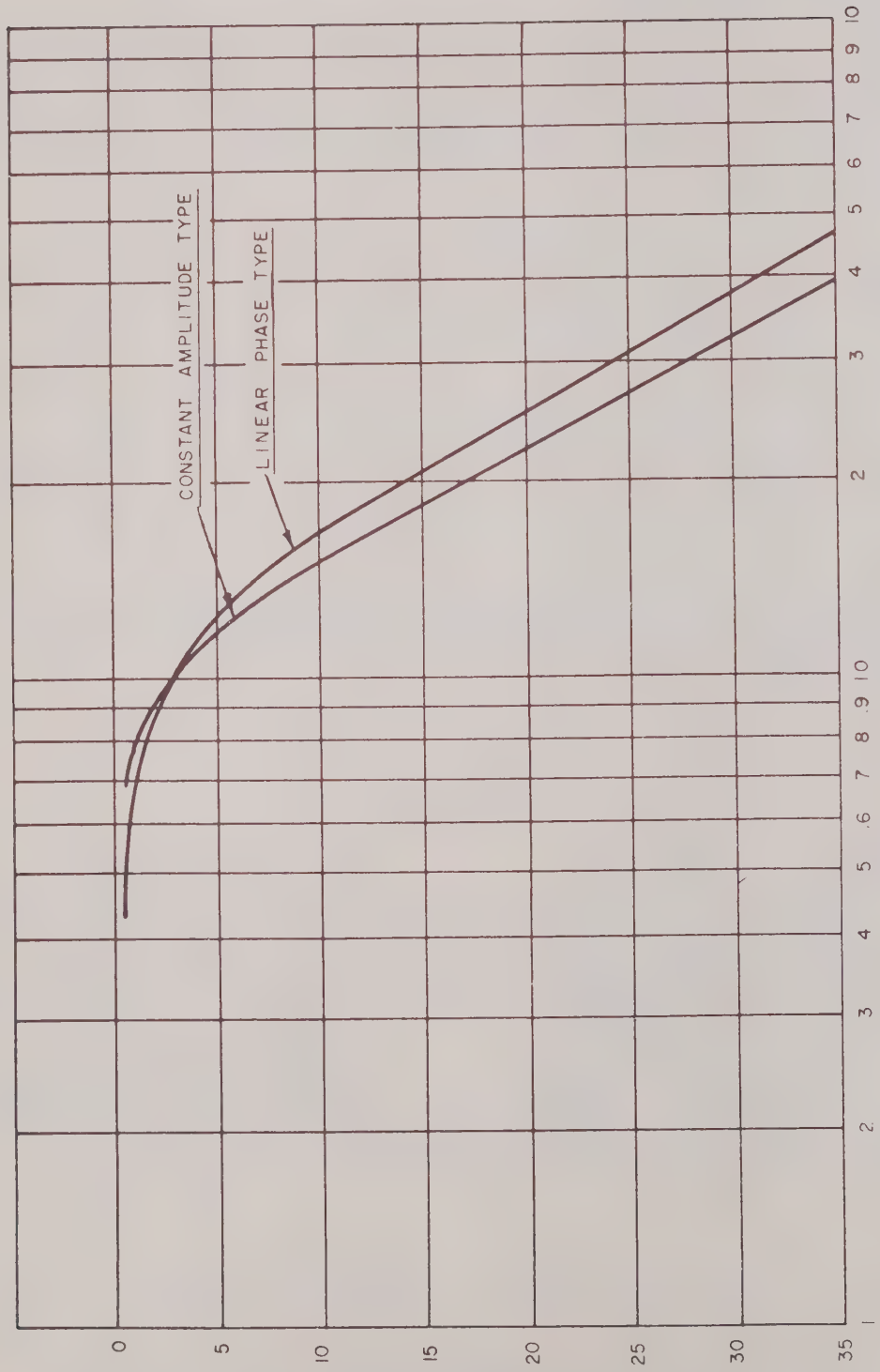


Figure 3-1. Low Pass Output Filter Amplitude Characteristics

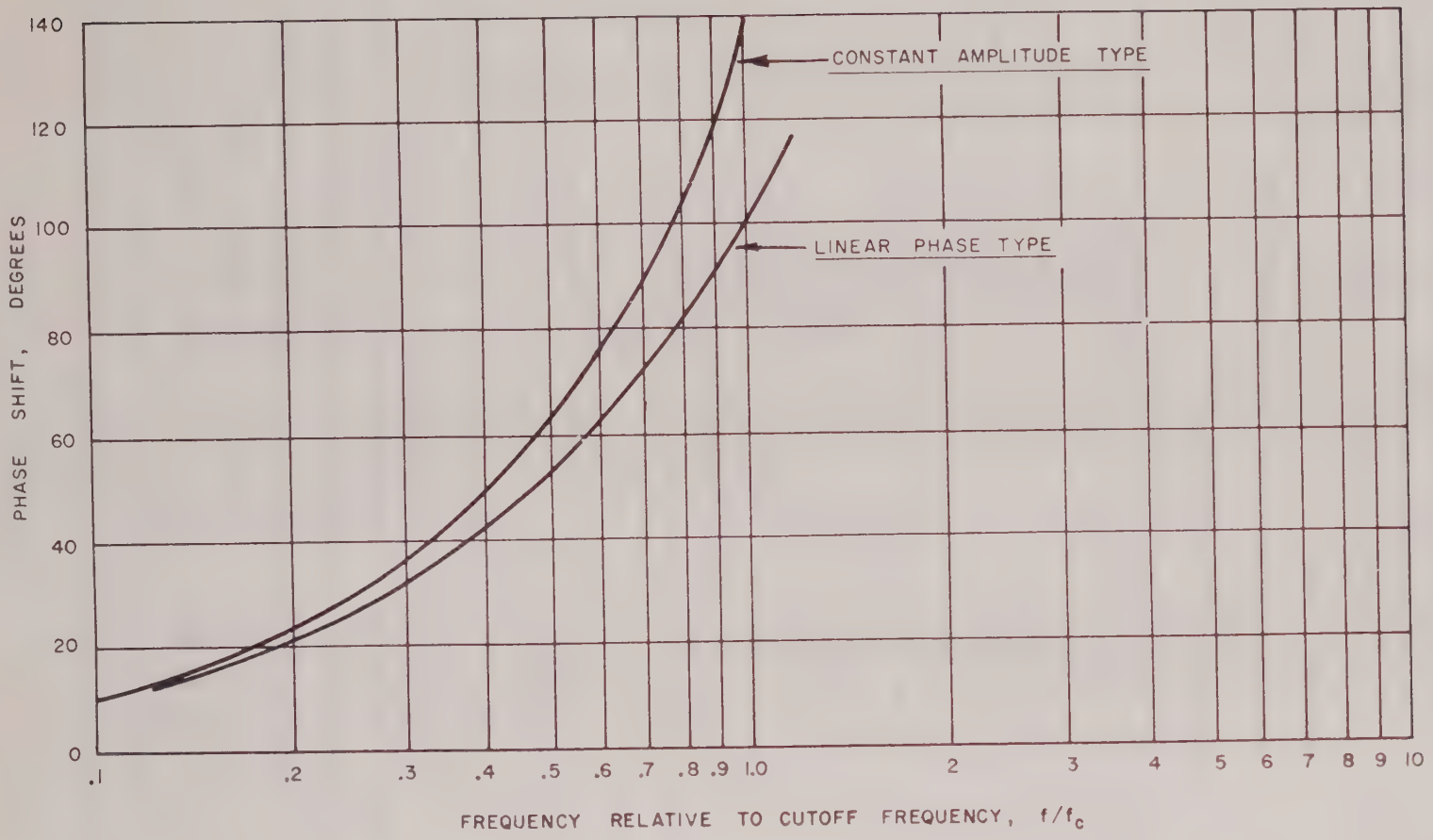


Figure 3-2. Low Pass Output Filter Phase Characteristics

3-10. In both cases the cutoff frequency is specified as the frequency at which the gain is 3 db below its low frequency or d-c value. Cutoff frequencies from 6 Hz to 100 kHz are available in either type. For a particular installation, the cutoff frequency should be chosen no higher than necessary to include the data bandwidth but to exclude high frequency noise. Table 3-1 lists the IRIG, AIA and DCS Constant Bandwidth subcarrier bands, and the recommended data bandwidth for each. Each subcarrier band can accommodate a greater data bandwidth than the value listed at the risk of reduced specifications.

3-11. CONTROLS AND INDICATORS (FIGURE 3-4).

a. Power Switch. The demodulator is placed in operation by depressing the POWER switch which lights when the unit is in operation.

b. Band Centering Adjustment. The purpose of the Band Centering Adjustment is to provide zero output voltage when the subcarrier input signal frequency is at band center. The control is a 10-turn screwdriver adjusted potentiometer, located on the front of the tuning unit. Allow at least 10 minutes warmup time before making the final band centering adjustment. At the input terminals apply a sinusoidal signal at band center frequency, having an amplitude between 2 millivolts rms and 2 volts rms. The Input Signal Level Meter should indicate the rms value of the input signal. (See next section.) Rotate the band centering adjustment (ZERO) control until the output meter is at center scale.

c. Input Signal Level Meter. The demodulator can function satisfactorily using input signals from 2 millivolts rms to 2 volts rms. The input signal level meter has 3 ranges: 20 mv, 200 mv and 2 volts rms full scale. The fourth switch position indicates the average loop phase error. If the input amplitude of the desired subcarrier is less than 2 millivolts rms, the Input Signal Level Meter indicates in the left hand portion of its scale when the input level meter range switch is in its 20 mv range. If the input signal amplitude is greater than 2 volts rms, the meter indicates in the far right hand edge of its scale when the input level meter range switch is in its 2 volt range. When the input signal amplitude is satisfactory for normal operation, the demodulator will operate properly regardless of the setting of the input signal level meter switch.

Table 3-1. Standard Tuning Unit and Low Pass Filter Frequencies

STANDARD TUNING UNIT FREQUENCIES

	Channel	Center Freq.	Deviation	Channel	Center Freq.	Deviation (Percent)	Channel	Center Freq.	Deviation (Percent)
IRIG FM/FM STANDARDS GFD-13/TU GFD-13/TUA	1	400 Hz	±7½%	11	7350Hz	±7½%	21	165,000 Hz	±7½%
	2	560	±7½%	12	10,500	±7½%	A	22,000	±15%
	3	730	±7½%	13	14,500	±7½%	B	30,000	±15%
	4	960	±7½%	14	22,000	±7½%	C	40,000	±15%
	5	1300	±7½%	15	30,000	±7½%	D	52,500	±15%
	6	1700	±7½%	16	40,000	±7½%	E	70,000	±15%
	7	2300	±7½%	17	52,500	±7½%	F	93,000	±15%
	8	3000	±7½%	18	70,000	±7½%	G	124,000	±15%
	9	3900	±7½%	19	93,000	±7½%	H	165,000	±15%
	10	5400	±7½%	20	124,000	±7½%			
DCS CONSTANT BANDWIDTH STANDARDS GFD-13/TU	MARK 1000	6.25 kHz	±1 kHz	MARK 2000	12.5 kHz	±2 kHz	MARK 4000	25 kHz	±4 kHz
		10.0	±1 kHz		20.0	±2 kHz		40	±4 kHz
		13.75	±1 kHz		27.5	±2 kHz		55	±4 kHz
		17.5	±1 kHz		35.0	±2 kHz		70	±4 kHz
		21.25	±1 kHz		42.5	±2 kHz		85	±4 kHz
		25.0	±1 kHz		50.0	±2 kHz		100	±4 kHz
		28.75	±1 kHz		57.5	±2 kHz		115	±4 kHz
		32.5	±1 kHz		65.0	±2 kHz		130	±4 kHz
		36.25	±1 kHz		72.5	±2 kHz		145	±4 kHz
		40.0	±1 kHz		80.0	±2 kHz		160	±4 kHz
DCS CONSTANT BANDWIDTH STANDARDS GFD-13/TU	MARK 8000	50 kHz	±8 kHz	MARK 16,000	100 kHz	±16 kHz	MARK 32,000	200 kHz	±32 kHz
		80	±8 kHz		160	±16 kHz		320	±32 kHz
		110	±8 kHz		220	±16 kHz		440	±32 kHz
		140	±8 kHz		280	±16 kHz		560	±32 kHz
		170	±8 kHz		340	±16 kHz		680	±32 kHz
		200	±8 kHz		400	±16 kHz		800	±32 kHz
		230	±8 kHz		460	±16 kHz		920	±32 kHz
		260	±8 kHz		520	±16 kHz		1040	±32 kHz
		290	±8 kHz		580	±16 kHz		1160	±32 kHz
		320	±8 kHz		640	±16 kHz		1280	±32 kHz
AIA CONSTANT BANDWIDTH STANDARDS GFD-13/TU	1 C	12.5 kHz	±2 kHz	2 CW	20.8 kHz	±4 kHz			
	2 C	20.8	±2 kHz	4 CW	37.5	±4 kHz			
	3 C	29.2	±2 kHz	6 CW	54.2	±4 kHz			
	4 C	37.5	±2 kHz	8 CW	70.8	±4 kHz			
	5 C	45.8	±2 kHz	10 CW	87.5	±4 kHz			
	6 C	54.2	±2 kHz	12 CW	104.2	±4 kHz			
	7 C	62.5	±2 kHz	14 CW	120.8	±4 kHz			
	8 C	70.8	±2 kHz	16 CW	137.5	±4 kHz			
	9 C	79.2	±2 kHz	18 CW	154.2	±4 kHz			
	10 C	87.5	±2 kHz	20 CW	170.8	±4 kHz			
	11 C	95.8	±2 kHz	22 CW	187.5	±4 kHz			
MAGNETIC RECORDING STANDARDS GFD-13/TUW	27		±40%	54 kHz 108 216		±40% ±40% ±40%			
REFERENCE FREQUENCIES GFD-13/RTU	(800 kHz, 400 kHz), 200 kHz, 100 kHz, 50 kHz, 25 kHz and 17 kHz								

STANDARD LOW PASS FILTER FREQUENCIES

	Band	MI-5 Freq. (Hz)	MI-1 Freq. (Hz)	Band	MI-5 Freq. (Hz)	MI-1 Freq. (Hz)	Band	MI-5 Freq. (Hz)	MI-1 Freq. (Hz)
IRIG FM/FM STANDARDS GFD-13/TU/L GFD-13/TU/LSM	1	6	30	11	110	550	21	2500	12,500
	2	8.4	42	12	160	800	A	660	3300
	3	11	55	13	220	1100	B	900	4500
	4	14	70	14	330	1650	C	1200	6000
	5	20	100	15	450	2250	D	1600	8000
	6	25	150	16	600	3000	E	2100	10,500
	7	35	175	17	790	3950	F	2800	14,000
	8	45	225	18	1050	5250	G	3700	18,500
	9	59	295	19	1400	7000	H	5000	25,000
	10	81	405	20	1900	9500			

CONSTANT BANDWIDTH AND OTHERS					
GFD-13/TU/L GFD-13/TU/LSM	250 Hz	2000	5000	16,000	40,000
	500	2500	8000	20,000	50,000
	1000	4000	10,000	25,000	

Standard Frequencies and Deviations

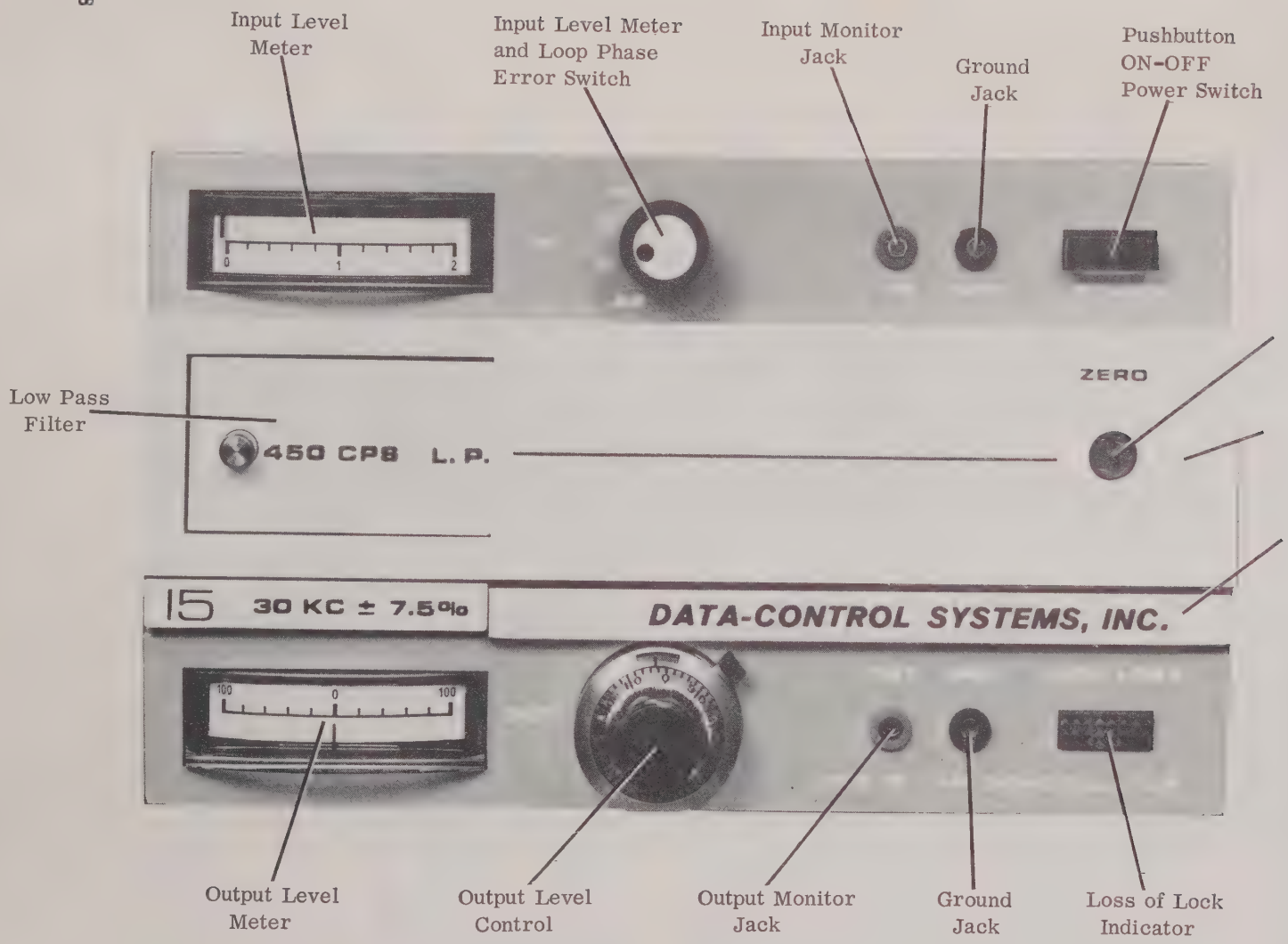


Figure 3-4. Controls and Indicators

For satisfactory operation of the demodulator, the input amplitude of the desired subcarrier must be adjusted for an input signal level of between 2 mv and 2 volts rms. (The meter indicates only the amplitude of the subcarrier selected by the band pass filter, and not the amplitude of the multiplex of subcarriers at the discriminator input.)

d. Output Level Control. A nine-turn finger operated potentiometer is provided for setting the output signal level. Maximum output voltage is ±10 volts at bandedges; minimum output voltage is ±1 volt at bandedge. Set this control for the required full scale input voltage to be applied to the recording equipment. A calibrate dial is available as an option.

e. Output Level Meter. The output level meter indicates demodulator output voltage expressed as a percentage of the maximum output voltage at bandedge (not the voltage setting of the output level control). Its calibration is -100%, 0, +100%. The meter indication is not dependent upon the setting of the output level control. Hence, after proper adjustment of the centering control has been made, its indication is also a measure of the frequency deviation of the input signal to the demodulator.

f. Monitor Jacks. An input signal monitor jack and an output signal monitor jack are provided on the front panel. Each is a pin-type receptacle. The input signal monitor jack is connected following the band pass filter so that only the subcarrier selected by the band pass filter will be observed. The actual output voltage as determined by the output level control is connected to the output signal jack.

g. Loss of Lock Indicator. The loss of lock indicator lights whenever the voltage controlled oscillator fails to remain synchronized with the incoming subcarrier (see Theory of Operation). When the indicator is lighted, the demodulator output voltage is not proportional to the subcarrier input signal frequency deviation, and does not represent the telemetered data. Three frequent causes of loss of lock are (1) marginal or insufficient input signal amplitude, (2) high noise level on the input signal or (3) input signal frequency outside the pass band of the band pass filter. To determine the cause of a loss of lock indication check the input signal which may be observed by connecting an oscilloscope to the input signal monitor jack.

SECTION IV

THEORY OF OPERATION

4-1. GENERAL.

4-2. This section covers general and detailed theory of operation.

4-3. A RADIO TELEMETRY SYSTEM.

4-4. Figure 4-1 is a block diagram of a typical radio telemetry system. The purpose of the system is to convey data (temperatures, pressures, etc.) from an inaccessible source, such as a drone aircraft or missile, to a data recording station.

4-5. The data measured by the transducers is represented by an analog voltage which is used to modulate a voltage controlled frequency modulated oscillator (VCO). The output signal frequency from each VCO then represents the measured data. Each of these signals is called a subcarrier. Up to 21 different subcarriers may be used simultaneously. The subcarriers are added and their sum modulates a frequency modulated transmitter operating in the 216 - 235 mHz band.

4-6. At the receiving station, an FM receiver reproduces the sum of the subcarriers. This signal, containing all of the telemetered data, may be recorded on magnetic tape for future study. It is also fed to a group of data demodulators, one for each subcarrier channel. In each demodulator, a band pass filter selects a subcarrier channel and rejects all others. Each demodulator delivers an output voltage which is proportional to the deviation of the input subcarrier frequency from its band center value. Hence, the output voltage from each demodulator is an analog of the data transmitted on its subcarrier channel. Indicating meters may be used to display the data or the data may be recorded by means of recording oscillographs or chart recorders.

4-7. DATA DEMODULATOR.

4-8. Figure 4-2 is a simplified block diagram of the GFD-13 demodulator. The input signal to the demodulator is obtained from an FM receiver and is the sum of all of the subcarriers transmitted on one radio frequency channel. For satisfactory operation of the demodulator, this signal amplitude must be between 2 millivolts rms and 2 volts rms.

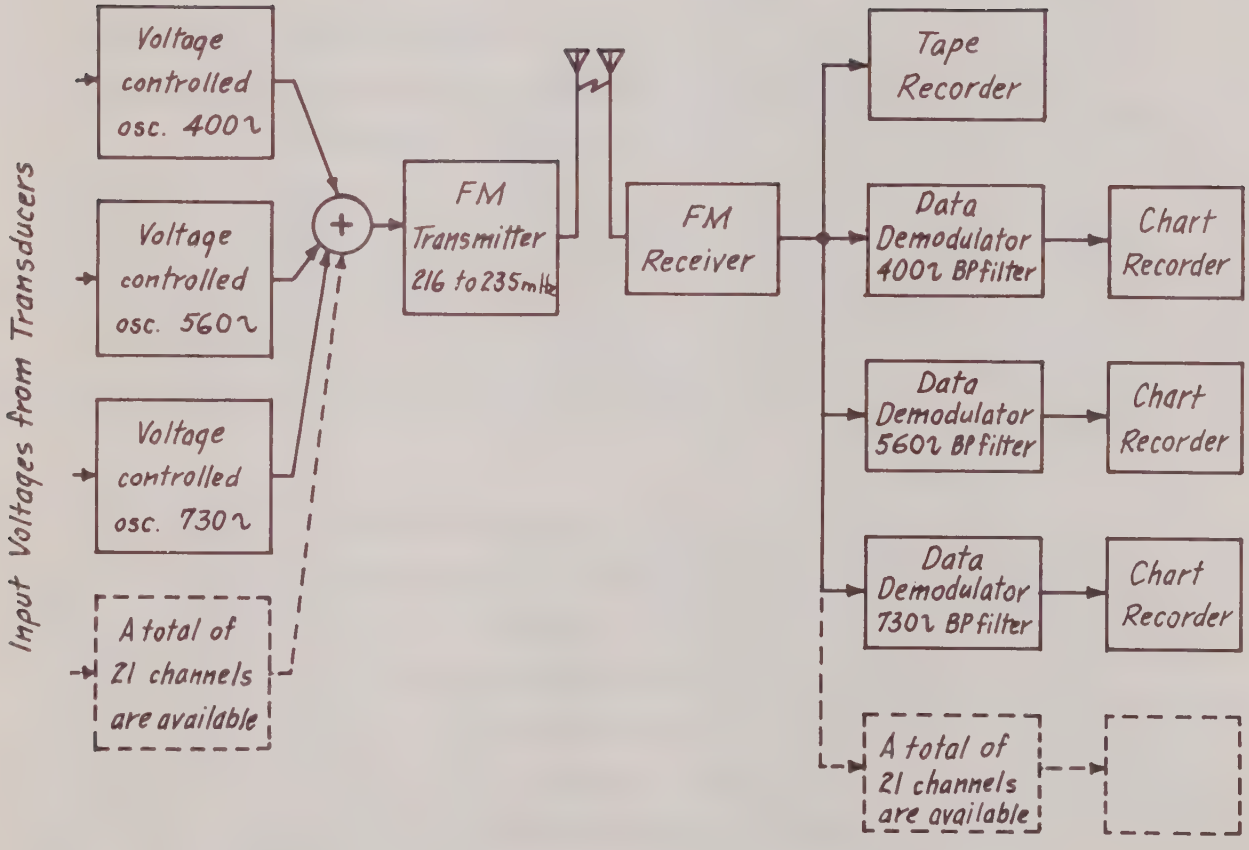


Figure 4-1. Radio Telemetry System, Block Diagram

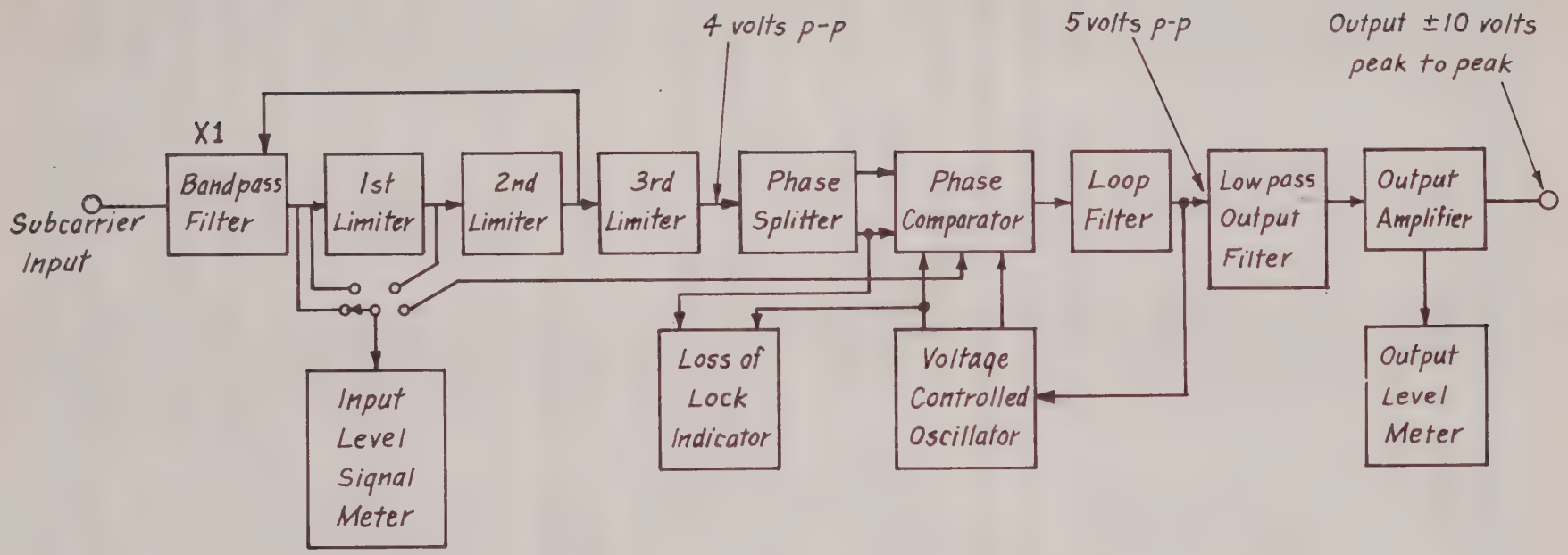


Figure 4-2. Data Demodulator, Block Diagram

4-9. High input impedance is provided by the first stage of the band pass filter which has an input impedance of greater than 500,000 ohms shunted by 50 pf maximum. The band pass filter has a voltage gain of one at its peak frequency.

4-10. The band pass filter, consisting of five stages of stagger-tuned LC amplifiers, selects the desired subcarrier signal and rejects all others. Its output signal consists of only the one desired frequency-modulated subcarrier. An isolation amplifier which follows presents a high impedance load to the last stage of the band pass filter to prevent detuning of its LC tuned circuit. The output signal from the band pass filter and following isolation amplifier is a sinusoidal waveform at subcarrier frequency. Three limiter stages convert this signal to a fixed-amplitude square wave at the subcarrier frequency. As long as the input signal amplitude is greater than the minimum required value of 2 millivolts rms, the output signal from the third limiter has a fixed amplitude of 4 volts peak-to-peak limited.

4-11. The demodulator output voltage should vary only with changes in the subcarrier frequency, but not with changes in the subcarrier amplitude; the limiters prevent variations of input signal amplitude from having any effect on the demodulator output voltage.

4-12. From the second limiter, a portion of the square wave signal voltage is fed back to the last stage of the band pass filter, which is tuned to subcarrier band center frequency. Signal phasing is arranged so that positive feedback results. The gain of an active circuit is the ratio of output amplitude to input amplitude.

$$G = \frac{\text{OUTPUT AMPLITUDE}}{\text{INPUT AMPLITUDE}}$$

4-13. For the combined limiter, the output amplitude remains constant at 4 volts peak-to-peak while its input may vary from 2 volts rms down to 1 millivolt rms or less. Referring to the definition of gain, it may be seen that the gain of the combined limiter increases as the input signal amplitude decreases. The lower the input amplitude, the higher the limiter gain. Hence, the gain around the loop consisting of the first two limiters, the fifth band pass filter stage, and the second isolation amplifier, increases as input amplitude decreases. When the subcarrier amplitude falls to about 1.5 millivolts rms, this loop gain increases to unity and the loop oscillates because of the positive feedback phasing. The frequency of the oscillation is at subcarrier band center since the loop contains a tuned circuit in the fifth band pass filter stage which is resonant at band center. The oscillation

forces the demodulator output to zero (corresponding to an input at band center) whenever the input amplitude falls too low. When the input amplitude is sufficient for satisfactory demodulator operation, the oscillation stops, and the demodulator output voltage is once again determined by the input subcarrier signal frequency.

4-14. Because the input signal amplitude may vary over a wide range and still yield satisfactory demodulator operation, the input signal level meter must operate over a large range. Thus, the input signal level meter has three levels of input range, 20 mv, 200 mv, and 2 volts rms full scale. It should be noted here that the demodulator works independently of the range at which the input signal level meter is set.

4-15. A 4 volt peak-to-peak square wave at the subcarrier frequency is connected from the third limiter to the phase-locked loop demodulator.

4-16. The phase-locked loop demodulator generates a voltage which is proportional to the deviation of the subcarrier frequency from its band center value. Hence, the output signal voltage from the phase-locked loop demodulator is an analog of the telemetered data. How the phase-locked loop demodulator functions is explained in the detailed circuit descriptions, paragraph 4-51.

4-17. PHASE-LOCKED LOOP DEMODULATOR. The purpose of the phase-locked loop demodulator (Figure 4-2) is to generate a voltage which is proportional to the deviation of the input subcarrier signal frequency from its band center value.

4-18. A constant amplitude square wave at subcarrier frequency is obtained from the third limiter. From this signal a phase-splitter provides two equal amplitude square waves, one in phase with the input and the other 180° out of phase with the input. These out of phase signals are connected to a phase comparator circuit. A tunable multivibrator, called a voltage controlled oscillator (VCO), generates two equal amplitude square waves, one 180° out of phase with the other, which are also connected to the phase comparator circuit. The frequency of oscillation of the VCO is determined by a frequency control voltage. The frequency is at subcarrier band center when the control voltage is zero (with proper centering adjustment); the frequency decreases as the voltage is made positive and increases as the voltage is made negative. A change in control voltage causes a proportional frequency change.

4-19. The phase comparator compares the relative phase of the push-pull subcarrier signal out of the phase-splitter to the push-pull VCO signal. It delivers fixed-amplitude square

wave current pulses at twice subcarrier frequency to the loop filter. In the loop filter, this current produces a pulsating voltage drop across an RC network which acts as a loop filter. When the VCO signal leads the subcarrier signal by exactly 90°, the square wave current pulses from the phase comparator are symmetrical, e.g., they have equal on and off time. Then the net or average voltage produced by the current pulses in the loop filter is zero.

4-20. If the VCO signal leads the subcarrier signal by more than 90°, the current pulses to the loop filter have shorter on time and longer off time. The net voltage produced by the loop filter is then positive. Similarly, if the VCO signal leads the subcarrier signal by less than 90°, the current pulses to the loop filter have longer on time and shorter off time, and the net voltage produced by the loop filter is negative.

4-21. Thus, by virtue of the phase comparing action of the phase comparator, the loop filter delivers a voltage that varies with the phase difference between the incoming subcarrier and the VCO; the voltage is zero when the VCO leads the subcarrier by exactly 90°, increasing positively if the VCO leads by more than 90°, and increasing negatively if the VCO leads by less than 90°. This voltage from the loop filter is fed back to control the frequency of the VCO. The feedback forms a phase-locked frequency control loop.

4-22. When the incoming subcarrier and the VCO are both at band center frequency, for example, and the VCO leads the subcarrier by exactly 90°, the VCO frequency control voltage is zero. Suppose the subcarrier were to increase in frequency. Instantaneously, then, a phase difference would begin to appear. In other words, the subcarrier would begin to advance or catch up to the VCO in relative phase. But the phase comparator and loop filter then produce a negative voltage which, when fed back to control the VCO, increases its frequency so that it remains very nearly 90° ahead of the subcarrier.

4-23. Thus, the VCO frequency remains "locked" to the subcarrier frequency. At band center they are 90° out of phase. An additional phase difference of less than 1° causes a sufficient change in the VCO frequency control voltage to drive the VCO frequency to bandedge.

4-24. As long as the VCO remains locked to the incoming subcarrier, its frequency control voltage is proportional to the deviation of the subcarrier frequency from band center. This voltage is therefore proportional to the telemetered data, and is fed to the output amplifier.

4-25. The VCO signal and the subcarrier are connected to a gate circuit called the loss of lock indicating circuit. Whenever there is a frequency difference or loss of lock, this circuit lights the loss of lock indicator.

4-26. The bandwidth of information which will be delivered to the demodulator output depends upon the frequency response of the loop filter. Since the information bandwidth varies with the subcarrier band frequency, the loop filter frequency response must be varied according to the chosen subcarrier band. The standard tuning unit contains the components of a fixed bandwidth loop filter whose cutoff frequency depends on the subcarrier band. A special tuning unit is available which contains a loop filter whose cutoff frequency is adjustable.

4-27. LOW PASS OUTPUT FILTER AND AMPLIFIER. The low pass output filter and amplifier determines the bandwidth of the demodulator output voltage or current, and amplifies this data signal to a level suitable for use by recording equipment. The filter and amplifier function as a unit as shown in Figure 4-3A. A portion of the filter network provides negative feedback around a high gain d-c amplifier. At very low frequencies, the overall gain from input to output is determined by the resistors. At a frequency approaching cutoff, the shunt capacitors attenuate the input signal and cause a gain reduction. Near cutoff frequency the feedback capacitor provides more negative feedback which causes a further gain reduction. With proper choice of component values the circuit will have a single cutoff frequency beyond which its gain falls off at a rate of 18 db per octave. The overall frequency response is shown in Figure 4-3B.

4-28. The high gain d-c amplifier shown in Figure 4-3A actually consists of three individual amplifiers. An output voltage limiter, level control, and level meter are also included. The complete system is shown in Figure 4-3C.

4-29. In the complete amplifier there are two parallel signal paths. Signals in the frequency band from 0 to approximately 60 Hz are amplified by a chopper amplifier. Its square wave or chopped output is filtered by an RC filter network, and connected to the input of a broad band d-c amplifier. Signals above approximately 60 Hz are capacitively coupled directly to the input of the broad band d-c amplifier, following which a power amplifier increases the signal power to the desired output power level.

4-30. A diode clamping circuit is connected from the amplifier output to its input. When the demodulator output voltage rises to a predetermined level, the clamping circuit prevents

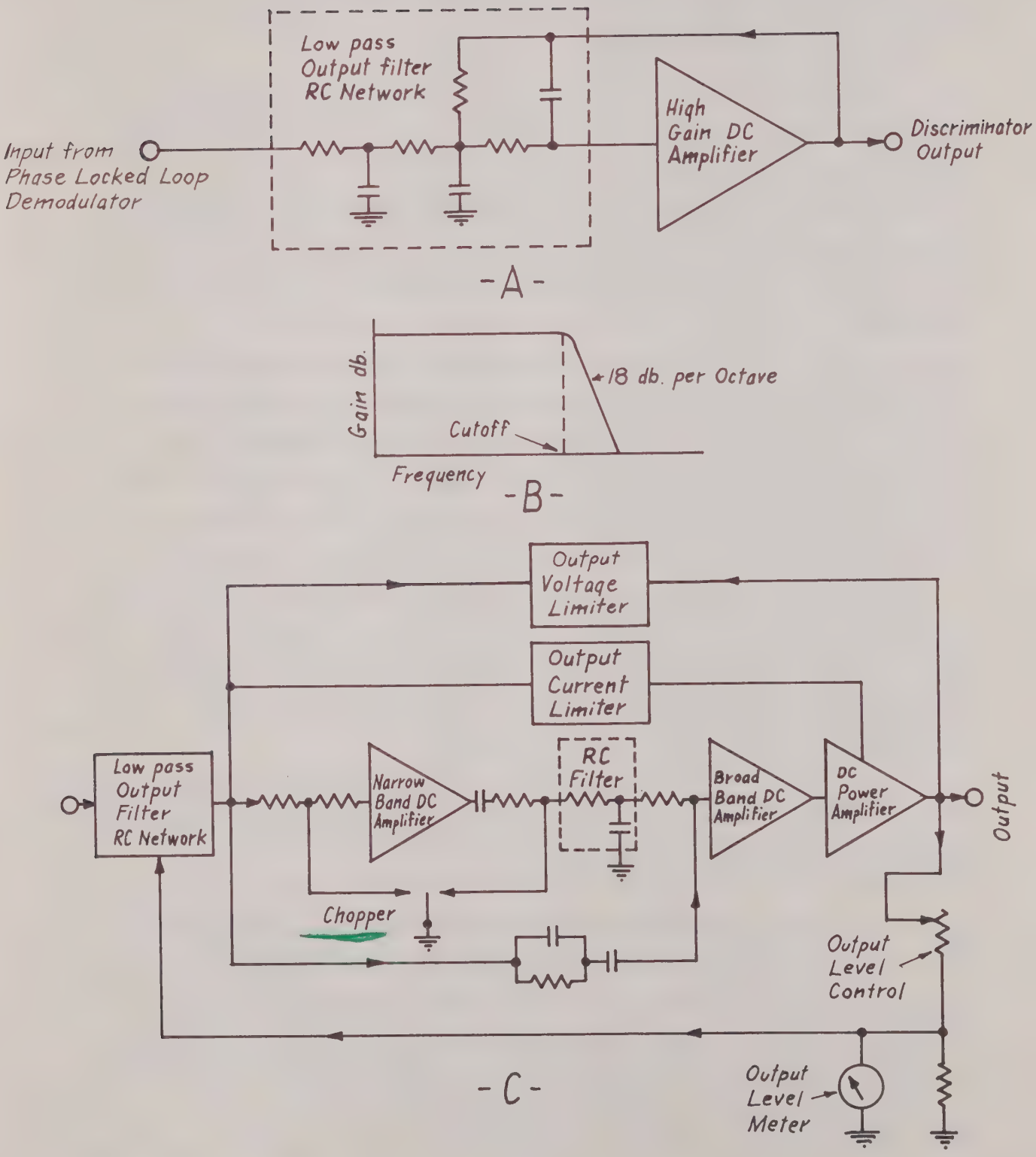


Figure 4-3. Low Pass Output Filter and Amplifier, Schematic

any additional increase in the amplifier input voltage, and hence, the output voltage cannot increase further. Clamping or limiting action occurs when the output voltage reaches ±13 volts.

4-31. A transistor clamping circuit is connected from the amplifier output stages to its input. When the demodulator output current rises to a predetermined level, the clamping circuit feeds a correcting current into the input and holds the maximum output current to 150% of specified current.

4-32. The output level control functions by controlling the amount of negative feedback around the amplifier. Because the output level meter is connected in the feedback path following the level control, its indication is independent of the setting of the level control.

4-33. DETAILED CIRCUIT DESCRIPTION.

4-34. BAND PASS FILTER. The input of the demodulator is connected directly to the input band pass filter through capacitor C3101 (see Figure 4-4). The input impedance of this band pass filter is above 500,000 ohms and is made up of resistor R3102 in parallel with the transistor impedance of Q3100. The band pass filter has a voltage gain of one and all components are contained in the center section of the tuning unit assembly.

4-35. The band pass filter consists of five stages of amplification. In each stage the collector load is a parallel resonant RLC circuit stagger-tuned to yield the required pass band. This adjustment should be made only at the factory. Each stage of the band pass is made up of one transistor. The first stage, Q3100, is an NPN type transistor; the second and fourth stages, Q3101 and Q3103, use PNP type transistors; and the third and fifth stages, Q3102 and Q3104, use NPN type transistors. This arrangement allows direct coupling between stages which avoids attenuation and frequency response difficulties encountered with interstage coupling networks.

4-36. LIMITERS. The first limiter has a gain of ten for low level inputs; limiter action does not take place until an input level of approximately 100 millivolts peak-to-peak is introduced. Isolation from the 5th stage of the band pass filter is accomplished by an isolation amplifier consisting of transistors Q3105 and Q3106 at the output of the band pass filter. The second limiter has a gain of 20 for low level inputs and limiter action does not take place until the input to the second limiter is approximately 50 millivolts. Thus, when the input to the first limiter is approximately 5 millivolts the output of the first limiter will be approximately 50 mv and the second limiter will begin to limit.

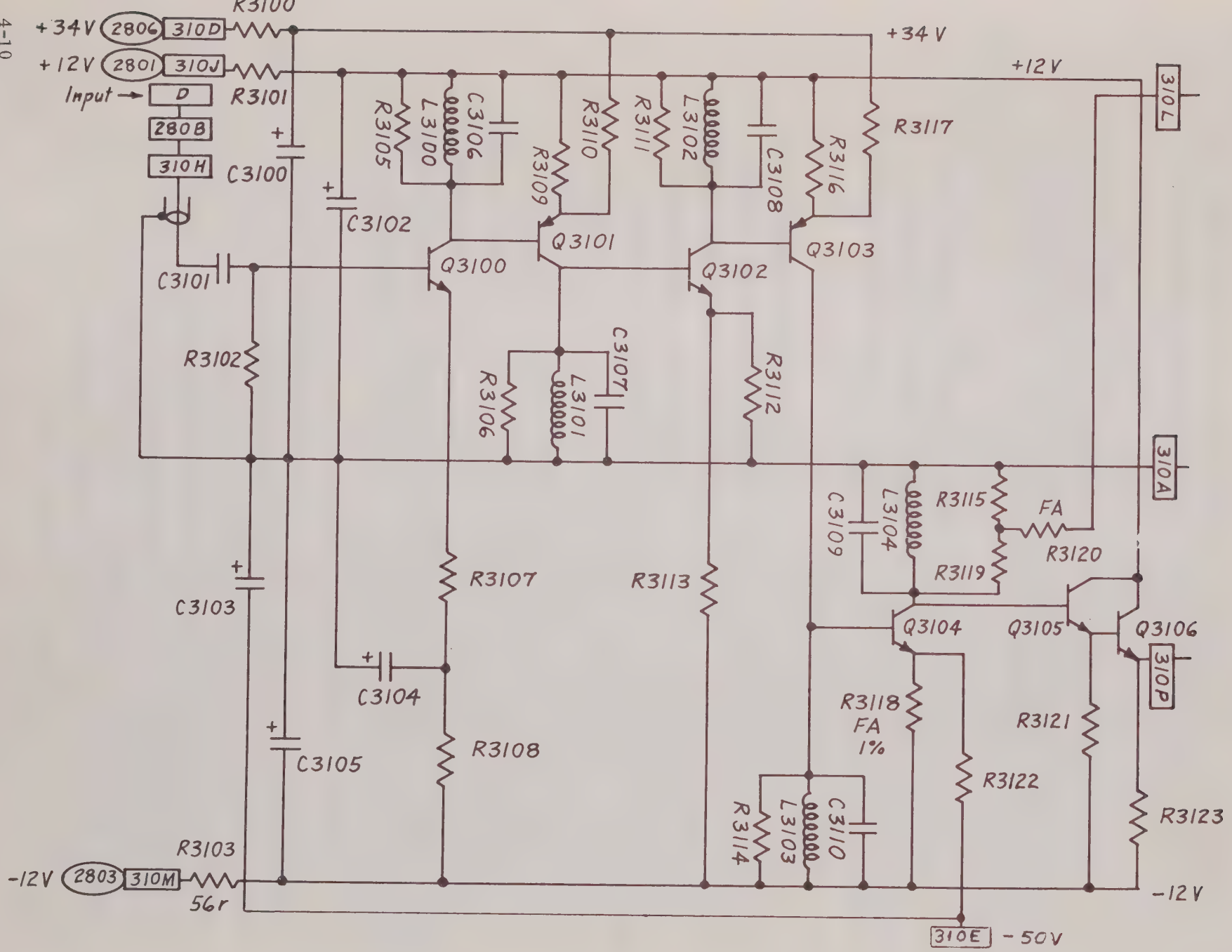


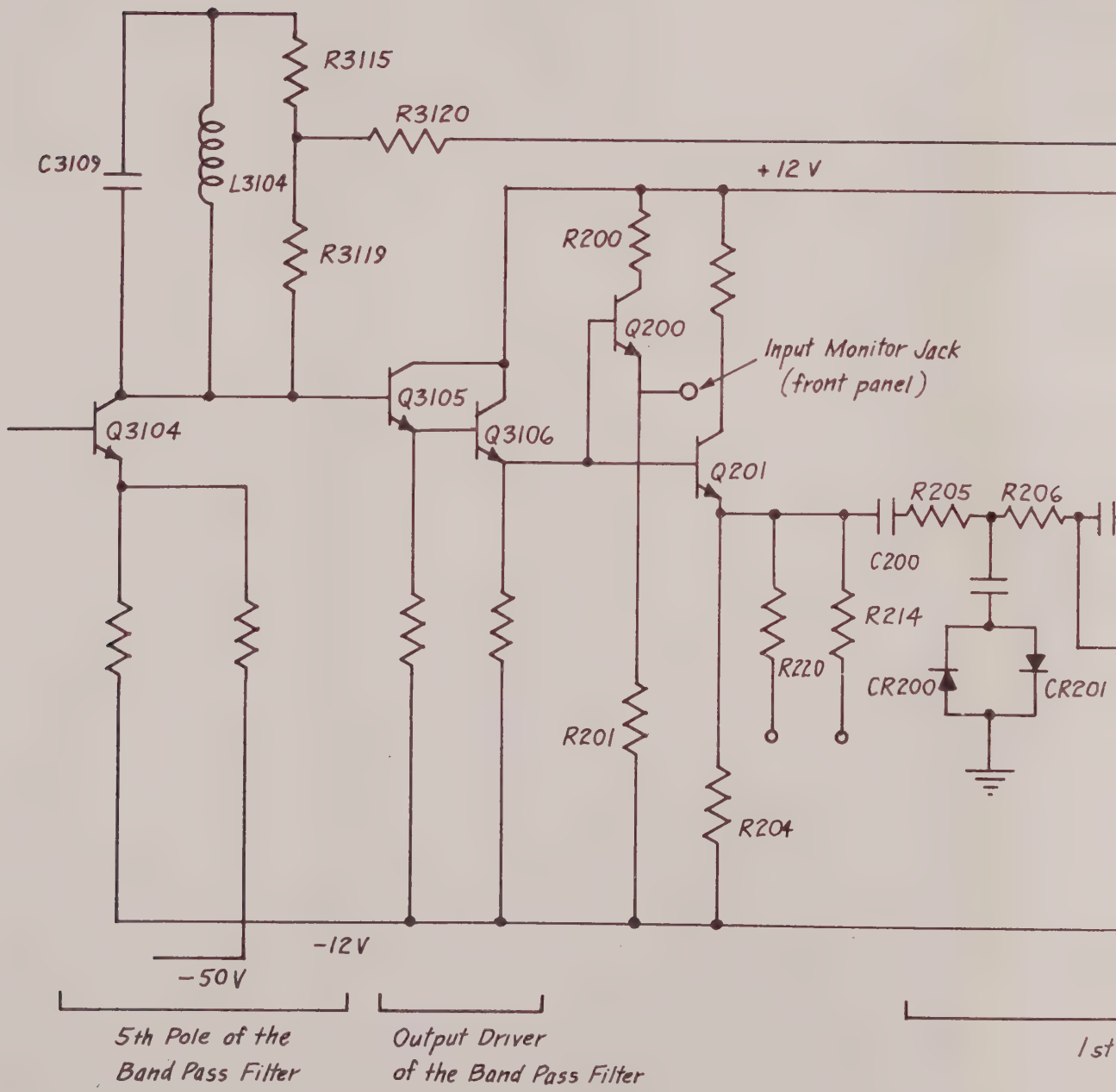
Figure 4-4. Band Pass Filter, Schematic

4-37. The third limiter has a gain of approximately 35 for low level inputs and is continually in operation. With an input to the first limiter of approximately 0.5 millivolts the third limiter will start limiting. However, when the input of the first limiter is reduced to about 1.5 millivolts the feedback around the first and second limiters starts the fifth pole of the band pass filter oscillating. This oscillation causes an input to the first limiter of above 1.5 mv and the third limiter will limit. Hence, the input can never be reduced to a low enough level to keep the third limiter from limiting.

4-38. Direct coupling is used between the emitter of Q3106 and the base of Q200 and Q201 (see Figure 4-5). Transistor Q200 is an emitter-follower that decouples the output of the band pass filter from the front panel input monitor jack. The monitor point shows only the input for this particular demodulator and not the complete multiplex. Transistor Q201 is an emitter-follower that drives the first limiter section and the first two levels of the meter switch.

4-39. In the first limiter primary limiting is done with the diodes CR200 and CR201. These are germanium diodes, the only germanium units used in this demodulator, and are used because of the low voltage drop and high conductance in the forward or conductive direction. The input signal is limited to approximately 0.6 volts peak-to-peak. Final limiting in the first limiter is done with the diode feedback amplifier consisting of the transistors Q202 and Q203 and the diodes CR202 and CR203. Section Q202 acts as a voltage amplifier and Q203 acts as an emitter-follower to provide low output impedance. R211 is the feedback resistor for the amplifier. When the output signal to the emitter of Q203 rises to a level which is approximately equal to the contact potential of diode CR203, the diode becomes conducting, greatly increasing the amount of negative feedback. The overall gain of this amplifier becomes much less than one. Also, when the emitter of Q202 goes down to a level which is approximately equal to the contact potential of diode CR202, the diode conducts, greatly increasing the amount of negative feedback, and the overall gain on this amplifier becomes much less than one. The normal gain of this amplifier is adjusted for a gain of ten when the input signal is low. This gain of ten is used in the input level meter circuit and is described in paragraph 4-45.

4-40. The output of the first limiter is passed to the second limiter by the capacitor C210 and resistor R217. The operation of this second limiter functions in the same way as the latter part of the first limiter. Thus, the second limiter provides additional square shaping action.


R3115
R3120
C3109
L3104
+12 V
R3119
R200
Q200
Input Monitor Jack
(front panel)
Q3105
Q3104
Q3106
Q201
R205
R206
C200
R214
R220
CR200
CR201
R201
R204
-12V
-50V
5th Pole of the
Band Pass Filter
Output Driver
of the Band Pass Filter
1st

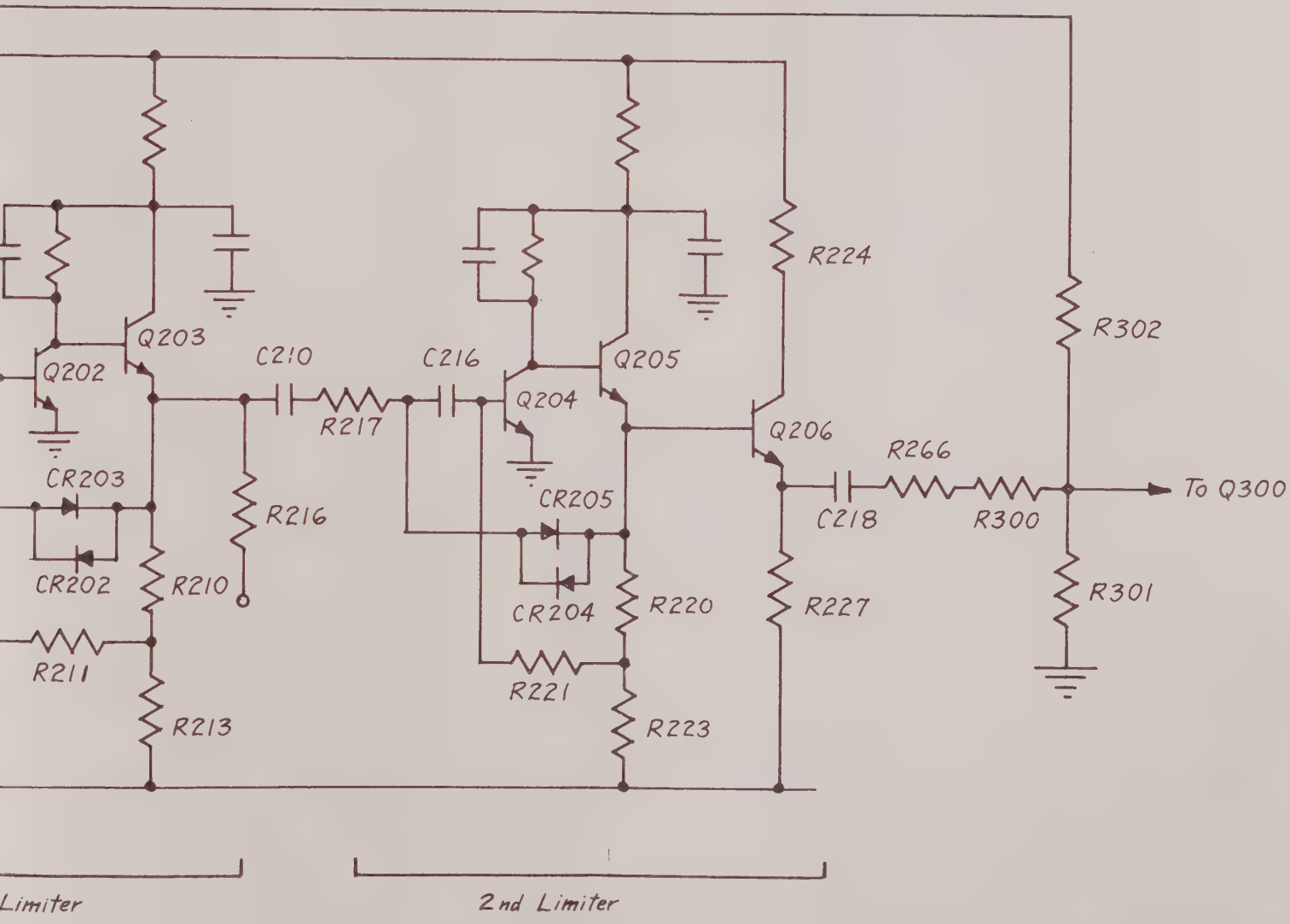


Figure 4-5. First and Second Limiter Stages

The amplitude of the output square wave is fixed by the contact potential of CR204 and CR205 in series just as in the first limiter. The output of the second limiter is connected to the base of an emitter-follower, transistor Q206. This output is fed through C218 and R226 both to the third limiter and back to the fifth pole of the band pass filter. When the subcarrier amplitude is low, the gain of the limiters is high. Then this loop will oscillate at the resonant frequency of the fifth tuned circuit, which is adjusted to subcarrier band center.

4-41. The limited output voltage of the first and second limiters are both approximately 1.2 volts peak-to-peak when they are limiting. When they are not limiting they have a gain of about ten and twenty, respectively.

4-42. THIRD LIMITER. The input of the third limiter is to the base of transistor Q300, an emitter-follower that isolates the third limiter from both the second limiter and the fifth pole of the band pass filter (see Figure 4-6). The signal is sent from the emitter of Q300 to the base of Q302 through C301, R305, and C302. Q302 is an amplifier. Q301 is a constant voltage source for a dynamic collector load of transistor Q302. Q303 is the emitter-follower output of the diode feedback third limiter.

4-43. The operation of the third limiter is the same as that of the first and second limiters except that it has a low level gain of about 35. R310 is the feedback resistor. There are four diodes used in the diode limiting section of this limiter. Thus, in order for the diode limiter to start operation, the peak AC voltage at the emitter of transistor Q303 must exceed that at the base of Q302 by the sum of the two diode junction voltages. Also, diodes CR302 and CR303 are not connected directly to the emitter of Q303 but to a voltage divider so that the ratio of resistors R312 and R313 plus R314 determines the voltage at which this circuit will limit. With the above feedback system the output voltage of the limiter will be approximately 4 volts peak-to-peak. The third limiter is at full limiting at all times during normal operation.

4-44. INPUT SIGNAL LEVEL METER. The input meter is provided with switchable full scale ranges of 20 millivolts, 200 millivolts and 2 volts rms. A fourth switch position on the input meter range switch is an average phase error indicator connected to the phase-locked loop. This indicator is a necessary adjunct to the use of extremely narrow loop filters to achieve maximum signal to noise threshold improvement. (See Figure 4-7.)

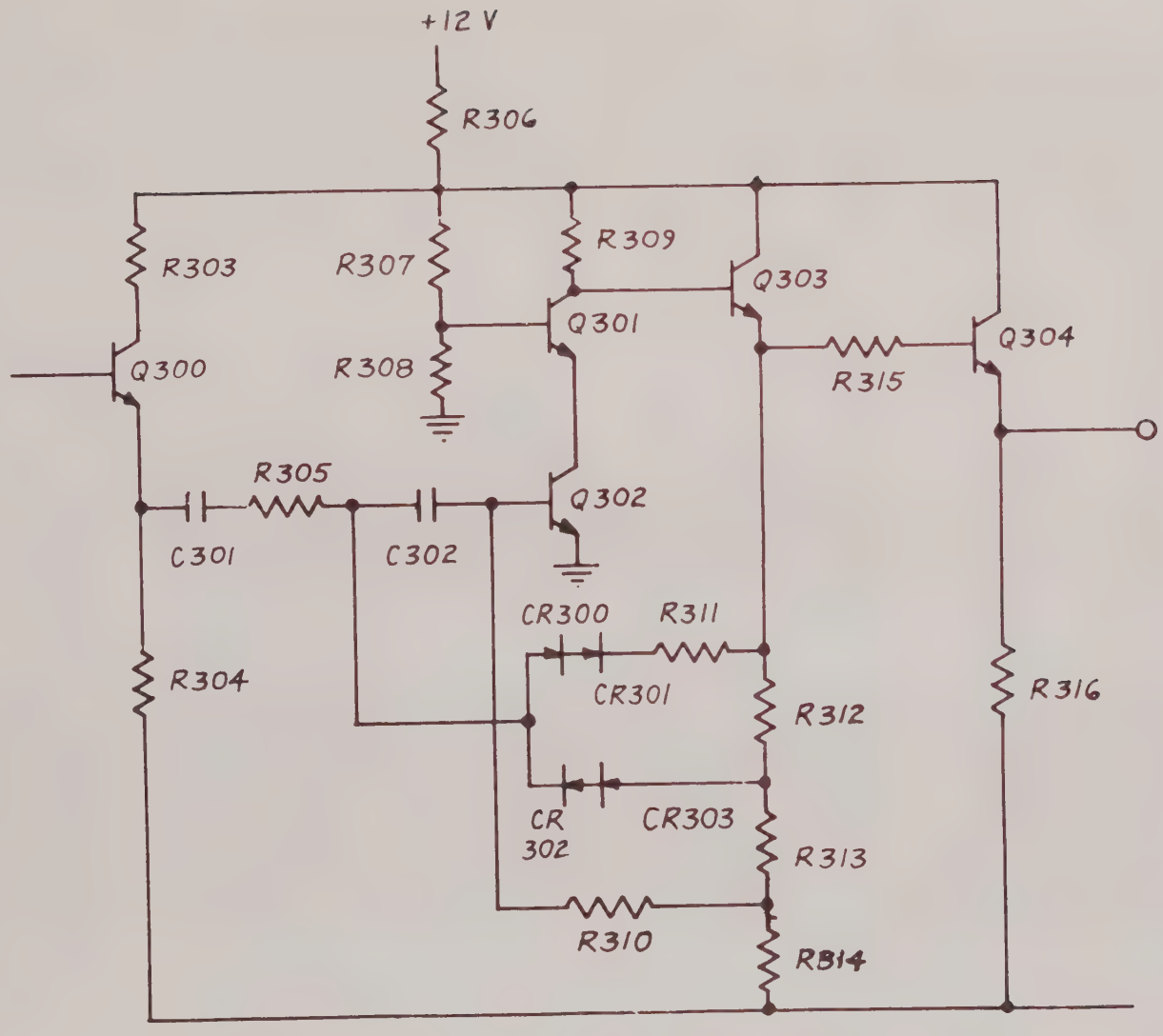


Figure 4-6. Third Limiter, Schematic

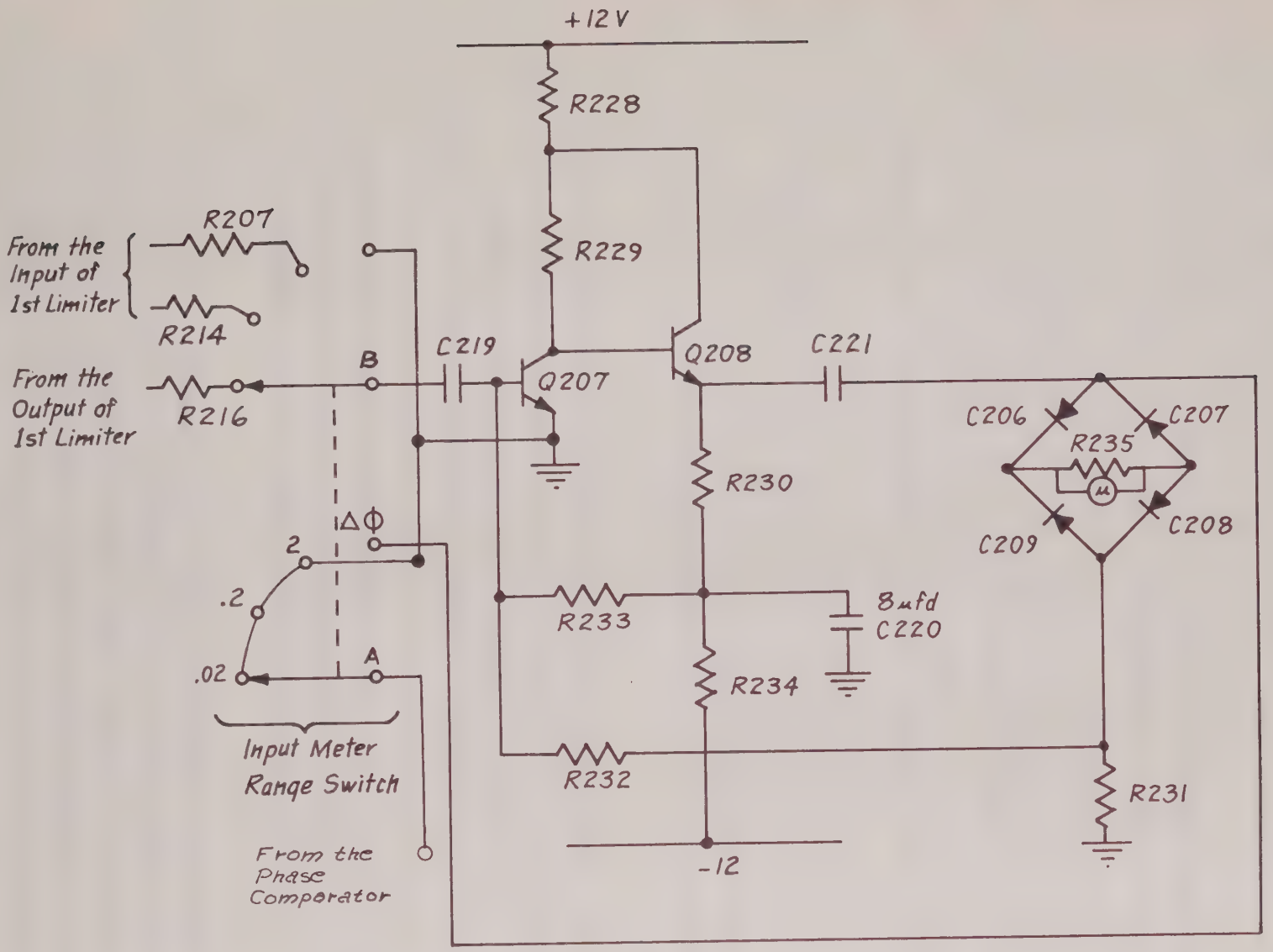


Figure 4-7. Input Signal Level Meter, Schematic

4-45. The input signal level meter circuitry is made up of a two transistor feedback amplifier with a bridge rectifier in the feedback loop. The input signal is fed through C219 to the base of Q207, the amplifier transistor. The collector of Q207 feeds the signal to Q208, an emitter-follower. The DC feedback path of this amplifier is through R233 to the base of Q207 and stabilizes the DC operation. It should be noted that there is no AC feedback through R233 because of the filtering effect of the capacitor C220.

4-46. The signal on the emitter of Q208 is fed through C221 to the bridge rectifier made up of the diodes CR206, CR207, CR208, and CR209 and fed back through R232 to the input base. The diodes in the rectifier are inside the AC loop. Thus, the diode characteristics do not effect the meter reading. The meter reads current and the resistor R235 is used in adjusting the current flow to calibrate the meter. R231 is an amplifier AC gain adjustment.

4-47. When the input meter range switch is in the 2 volt position, the emitter-follower driving the first limiter is connected to the input of the input signal level meter circuit through resistor R207. The gain of the input signal level meter circuit with R207 as its input resistor is designed for a full scale meter reading with a 2 volt rms input to the input of the demodulator.

4-48. When the input meter range switch is in the 200 millivolt position, R214 is the input resistor for the input signal level meter circuit. From the general schematic it can be seen that the resistor R214 has as its value about one tenth of that of resistor R207. It should now be apparent that a change in this amount of resistance will make a change in gain of ten in the input meter circuit gain because, this being a feedback amplifier, the gain changes with the ratio of the feedback resistor to that of the input resistor. The feedback resistor always being held constant in this case. Thus, if we decrease the value of the input resistor by ten the gain of the amplifier will be increased by ten and the sensitivity of the input circuit will increase by ten.

4-49. When the input meter range switch is in the 20 millivolt position R216 is the input resistor for the input signal level meter circuit. This resistor is at the output of the first limiter shown in Figure 4-5. At this low level into the demodulator, the first limiter circuit is not in its limiting mode but instead is in an amplifier mode controlled by the feedback resistor R211 and R212 and R205 and R206, and has a gain of ten as described in the section on the first limiter. This increases the input amplitude of the demodulator by a gain of ten if the input resistor value of the meter amplifier is kept the same as the 200 millivolt position.

4-50. When the input meter range switch is in the phase error position, the input for the input signal level meter amplifier is grounded and produces no AC input to the meter. However, the meter bridge is now connected to the phase comparator and measures the average current out of the demodulator.

4-51. PHASE-LOCKED LOOP DEMODULATOR. The square wave subcarrier is coupled from the third limiter to Q403 via C401. Q403 is a split-load phase inverter from which two push-pull signals are obtained and coupled directly to two of the four transistors in the phase comparator, Q412 and Q413 (see Figure 4-8). When the loop is locked, the VCO generates a push-pull square wave at the subcarrier frequency. The two signals are coupled directly to Q408 and Q409 of the phase comparator circuit.

4-52. The phase comparator is made up of transistors Q408, Q409, Q412 and Q413 and is a current switching circuit. Q414 and Q407 function as current sources. Current for the Q414 current source passes through either Q412 or Q413 depending on the phase splitter waveform. Only one of the two conduct at one time.

4-53. Assume that Q412 is conducting. Current must come either through Q408 or through Q410 and CR402. Notice Q408 and Q409 are switched by the VCO against the decoupled -12 V supply through the emitter of Q410 and Q411, respectively.

4-54. If Q408 is off while Q412 is conducting current must come through Q410 and CR402. Q413 is off during this period and CR403 prevents zener breakdown current from flowing through Q411. Even though Q409's base is more positive than the +12 volt supply, its emitter is effectively open and current from the Q407 source must flow into the loop filter (i.e. C3400, C3401 and R3405).

4-55. Now if Q408 turns on while Q412 is conducting, Q410 will turn off and the current from current source Q407 will flow through Q408 and Q412 and into source Q414. Current in source Q414 is twice the current from source Q407 so an equal amount of current must flow out of the loop filter.

4-56. The above action has occurred during one half the subcarrier cycle that Q412 is on and Q413 is off. A similar action takes place when Q413 is on and Q412 is off. If R420 is adjusted so that the current from source Q414 is exactly twice the current from source Q407, and if the VCO is exactly 90° out of phase with the incoming signal from the phase splitter, then equal and opposite currents will flow into and out of the loop filter every other quarter of a subcarrier cycle resulting in a symmetrical triangular voltage waveform across the loop filter with no change in average voltage.

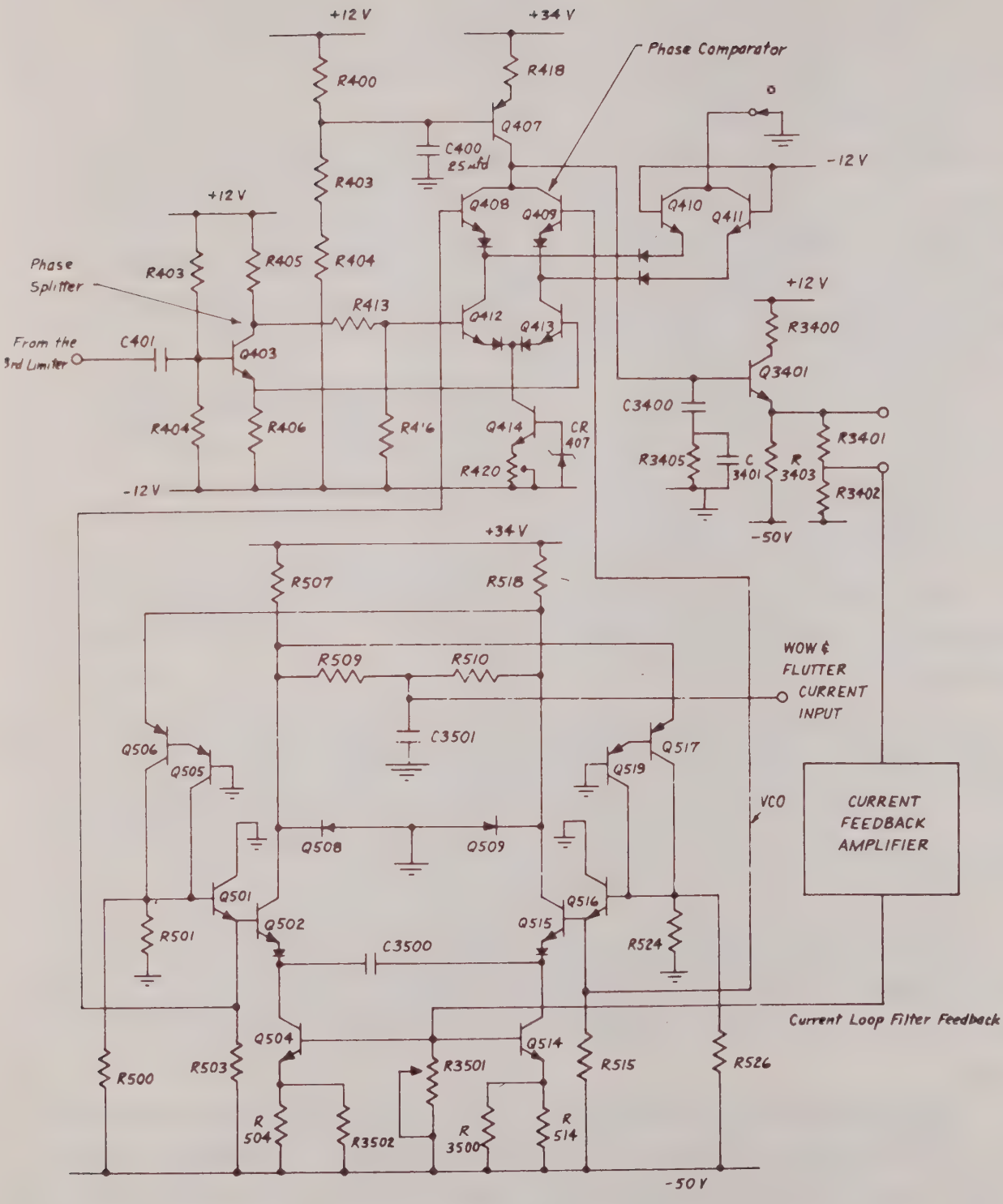


Figure 4-8. Phase Locked Loop Demodulator, Schematic

4-57. If the input frequency starts to change the phase between the inputs and VCO signals will move from its 90° relationship altering the duty cycle of the current flowing into and out of the loop filter. This will cause an average current to flow during each half of a subcarrier cycle giving an average voltage change across the loop filter. The loop filter is connected to the frequency control buss of the VCO. The net voltage change on the input to the VCO will change its frequency. As the VCO frequency starts to change the phase between the input and VCO frequencies will be corrected back toward the 90° static position. When the VCO frequency is the same as the input frequency and the phase adjusts to 90° the voltage of the frequency control buss will stop changing and the loop will be in static equilibrium. To remain in lock the VCO frequency must be the same as the input frequency and may not vary in phase by more than 90° ±90°.

4-58. Relationships between the various waveforms are shown in Figure 4-9. The first set shows the subcarrier lagging the VCO by 90° and the second shows the subcarrier lagging by more than 90°. Note that current can flow through Q408 only during the positive half cycle of its base voltage and only during the interval when Q412 is on. Similarly, current can flow through Q409 only during the positive half cycle of its base voltage and only during the interval when Q413 is on. Hence, Q408 and Q409 alternately allow square wave pulses of current at twice subcarrier frequency to flow to and from the loop filter.

4-59. When the subcarrier lags the VCO by exactly 90°, these current pulses are symmetrical, e.g., they have equal on and off durations. Net voltage produced by the current flowing in the loop filter is zero.

4-60. When the subcarrier lags the VCO by more than 90°, these current pulses become asymmetrical, e.g., they have shorter on time and longer off time. Net positive voltage is produced in the loop filter.

4-61. Similarly, when the subcarrier lags the VCO by less than 90°, the current pulses have longer on time and shorter off time, and a net negative voltage is produced in the loop filter. The voltage produced across the loop filter is amplified in power level by Q3400 and Q3401, a Darlington connected emitter-follower stage, fed back to control the VCO frequency and coupled to the output amplifier. Components of the loop filter and Darlington amplifier are located in the tuning unit.

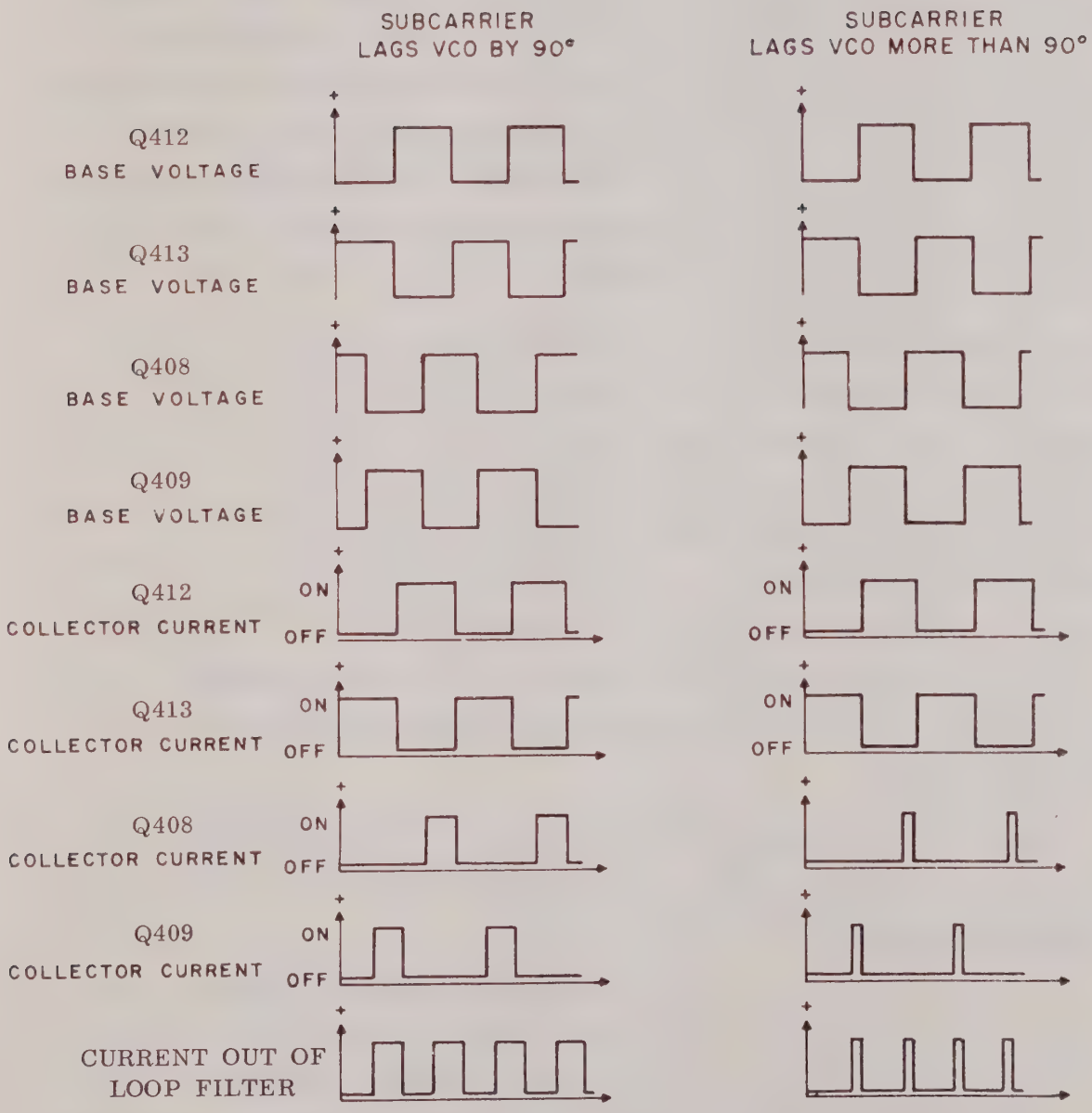


Figure 4-9. Waveforms in the Phase Locked Loop Demodulator

4-62. In the VCO, Q515 and Q502 operate as an astable multivibrator. Transistor Q503 and Q504 and transistors Q513 and Q514, connected in a Darlington arrangement (not shown as such on the simplified schematic), function as a single transistor to generate a steady current. Current generated by composite Q514 flows through Q515 when it is on, or otherwise through C3500 when Q515 is off and Q502 is on. The VCO output voltage amplitude at the collectors of Q515 and Q502 is clamped by diodes Q508, Q509 and composite transistors Q506 and Q519 to an amplitude which is dependent upon the diode bias voltages. It should be noted here that the diodes in the simplified Figure 4-8 are really transistors in true demodulator. The diode bias voltage for Q508 and Q509 is ground. Therefore, collectors of transistors Q502 and Q515, cannot go more negative than minus 0.7 volts.

4-63. Next consider the positive voltage clamping on the collector of Q502. Any time the voltage on the emitter of Q519 gets more positive than 1.4 volts above ground this transistor will start to conduct clamping the collector waveform. When Q519 conducts the voltage on the collector of Q502 will clamp at plus 1.4 volts minus the voltage drop across the diode Q507 which is 0.7 volts peak; thus, the collector is clamped at both plus and minus 0.7 volts peak.

4-64. Note that all diodes that have a Q number are really transistors in a diode configuration. This provides better temperature compensation on all junctions by using the same junction construction.

4-65. PHASE-LOCKED LOOP DEMODULATOR OPERATION. At the instant that Q502 begins to conduct, its collector voltage starts to swing negatively toward the diode bias produced by Q508. This collector voltage change in the negative direction turns transistor Q519 off. With no current flow through Q519 the voltage on the divider R524 and R526 and the base of Q516 is such that the transistor will be turned off. This will in turn, turn off Q515. With Q515 turned off its collector will be positive enough so that Q506 will be turned on and conducting. The conduction of Q506 will make the bias on the divider R500 and R501 and on the base of Q501 positive with respect to its emitter and thus turned on. The emitter of Q501 will then turn Q502 on. It should be noted that full conduction is not saturation. The abrupt change in emitter voltage at Q502 is coupled to the emitter of Q515 by the capacitor C3500. The emitter of Q515 is driven positive an amount equal to the voltage change on R500, R501 divider (about 10 volts). The base of Q515 is driven negative an amount equal to the voltage change on divider R524, R526 (about 10 volts). Q515 is then turned off by a 20 volt base to emitter voltage.

4-66. The steady current from Q504 flows through Q502 while Q502 is on. Because Q515 is off the steady current from Q514 flows through C3500 and Q502. At Q502 the emitter voltage is fixed at the base potential; but at Q515 the emitter voltage swings negative in a linear manner as C3500 charges, while the base voltage is held fixed by the voltage divider R524, R526. When the emitter voltage of Q515 gets sufficiently negative for Q515 to conduct, switching occurs and Q515 turns on while Q502 turns off. The point of conduction and switching occur when the base and emitter voltages of Q515 (the non-conducting transistor) become equal. During switching the rising collector voltage of Q502 turns on Q519. The conduction of Q519 into divider R524, R526 pulls the base voltage of Q516 positive, which in turn pulls the base of Q515 positive. The emitter base junction is forward biased at this time and it moves positive (approximately 10 volts).

4-67. Since the voltage across C3500 cannot change instantly, this abrupt transition drives the emitter of Q502 positively an equal amount. During the interval when Q502 is off and Q515 is on, current flow through C3500 is reversed and the emitter voltage of Q502 goes negative until it equals its base voltage and switching once again occurs. Waveforms on one transistor are shown in Figure 4-10. At the other transistor voltages are 180° out of phase. The time at which switching occurs depends upon (1) the base voltage of whichever transistor is off and (2) the rate at which C3500 charges. The base voltage of the transistor that is off is determined by the voltage divider R524 and R526 or R500 and R501. The rate at which C3500 charges is determined by the value of this capacitor and the current source rate of flow. The current source rate of flow is dependent upon the current source base voltages, Q504 and Q514, which determines the current flowing into the collectors of the transistors Q502 and Q515. The current into the collector of Q502 or Q515 is determined by both the current sources.

4-68. When either Q502 or Q515 is off their collector resistor becomes the emitter resistor of current source Q519 or Q506, respectively. These current sources determine the voltage change on dividers R524, R526 and R500, R501, respectively. It was shown above and in Figure 4-10 that these voltage changes determine the total voltage through which C3500 (the timing capacitor) must charge.

4-69. The frequency of this voltage controlled oscillator is, therefore, determined by the timing capacitor value (C3500), the current source current which flows through the timing

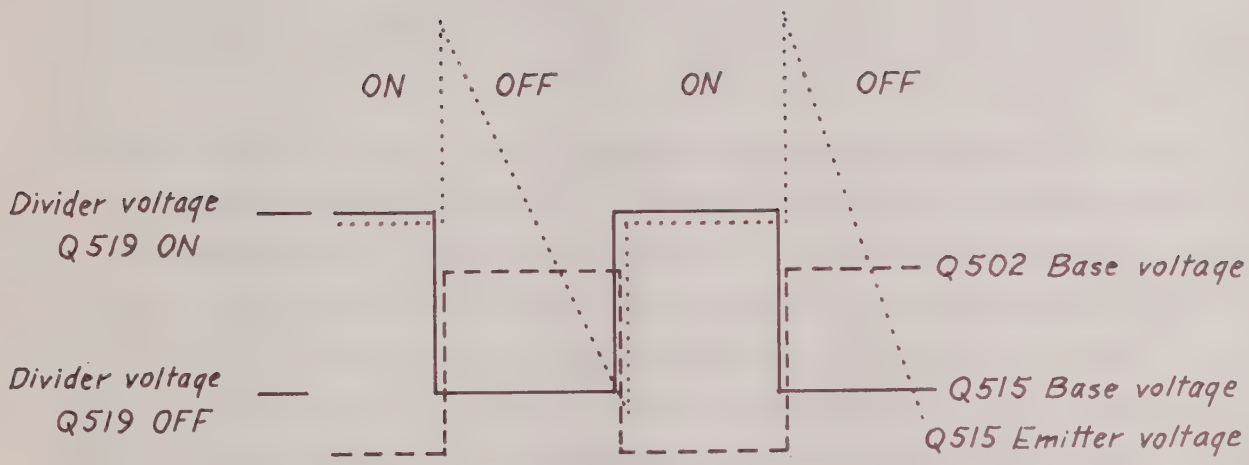


Figure 4-10. VCO Waveforms

capacitor and the voltage through which the timing capacitor must charge before the VCO switches (i.e. twice the divider voltage change). The frequency may be changed by changing any of these three. Channel center frequency is determined by the value of C3500. Variation of the frequency within the channel is accomplished by varying the current source current that flows through the timing capacitor. Q523, Q524 and Q525 are a precision current source that converts the frequency control buss voltage into a precise current. This current develops a precision voltage across R512, R3501 and Q511 and Q512. This in turn develops precision currents in current sources Q504, R504 and Q514, R514. Variation of the frequency control buss voltage then varies the charging current through C3500. R3501 is the zero control and allows parallel changes in the charging current.

4-70. Q520, Q521 and Q522 make up another current source. The current generated here is fed through R509 and R510 to the VCO collectors. When a VCO transistor (Q502 or Q515) is on this current only adds to the current from the collector resistor and diode to ground (R507, R518 and Q508, Q509, respectively) through each transistor to its current sources. Since the current sources (Q504 and Q514) determine the current, the diode and resistor together always deliver the proper current. When a VCO transistor is off, however, the accompaning diode is off and the current through R509 and R510 adds to the current through Q519 and Q506, respectively, and modifies the voltage change in the appropriate divider. This modifies the voltage through which C3500 must charge and, therefore, changes the frequency of the VCO.

4-71. The input to this current source (pin J) is connected to the tape speed compensation buss and this source is used to tape speed compensate the demodulator. R523 and C3502, when driven from a low impedance source, form an all pass phase shifter and C3501 acts in conjunction with R509 and R510 as a current low pass filter. These circuits delay the tape speed compensation signal an amount equal to the information delay in the band pass filter. C3501 and C3502 must change as the duration of the band pass filter changes and so they are located in the tuning units, as is C3500.

4-72. LOSS OF LOCK INDICATOR. The loss of lock circuit is shown in Figure 4-11. There are two square wave input signals to the loss of lock circuit, one from the VCO and one from the limiter. The limiter square wave is fed to the base of Q402 which is biased off. The amount of off bias is determined by this square wave.

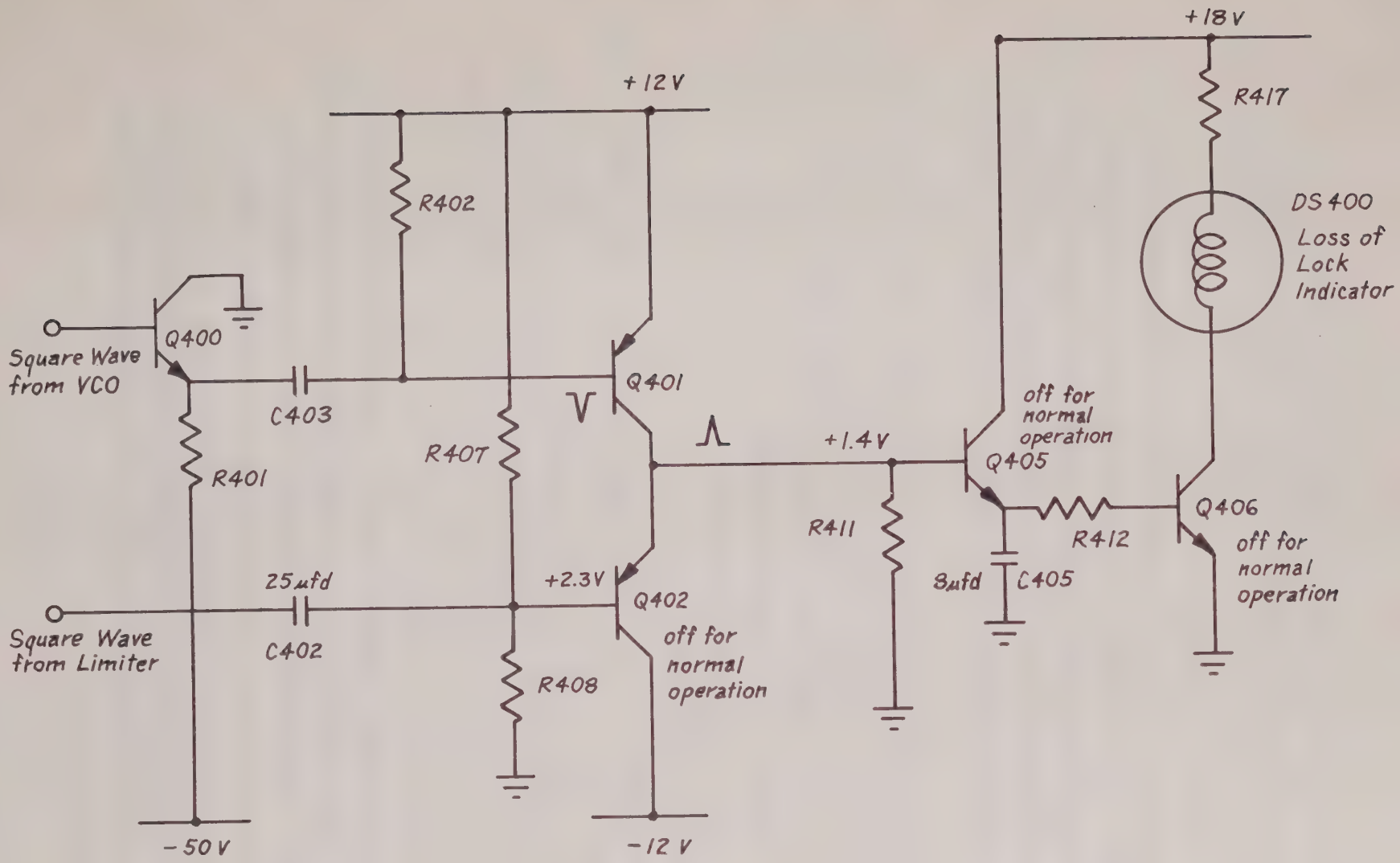


Figure 4-11. Loss of Lock Indicator, Schematic

4-73. The VCO square wave is connected to the base of Q400 (see Figure 4-11). The Q400 emitter is coupled to the base of Q401 with a small capacitor C403 which integrates the square wave and presents a short pulse to the base of pulse amplifier Q401. The signals on Q401, Q402 and Q405 are shown in Figure 4-12.

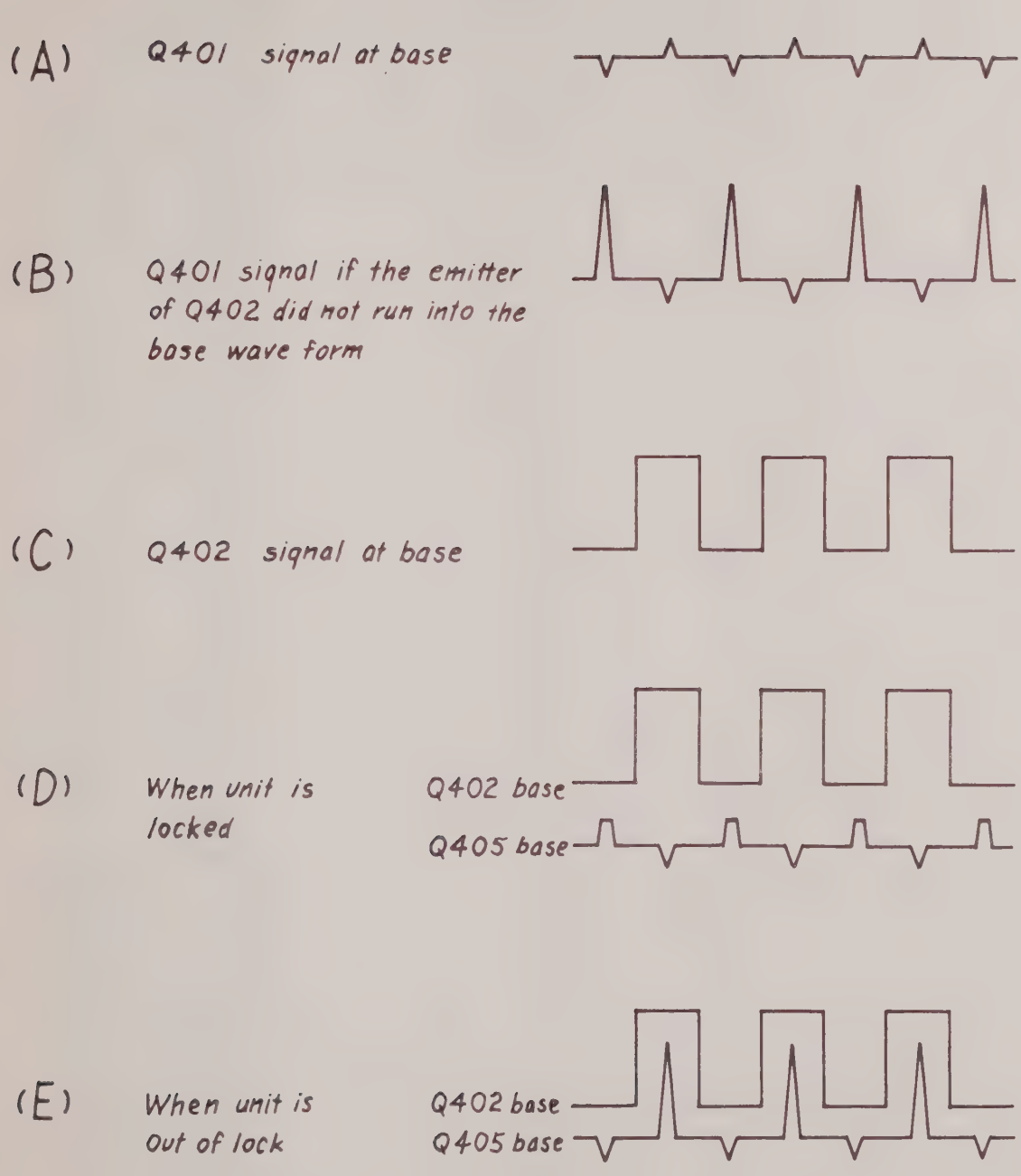
4-74. If the demodulator looses lock the pulses from Q401 will sometimes be shifted in phase 180° as shown in Figure 4-12E. When this happens the positive pulse on the base of Q405 is large enough to turn on Q406. C405 in the emitter of Q405 makes this stage a peak detector and holds Q406 on even after the pulse into Q405 is over. C405 discharges through R412 into Q406 with a relatively long time constant. Q406 operates Lock Loss light DS400.

4-75. LOW PASS OUTPUT FILTER. The low pass output filter is shown in Figure 4-13. The low pass output filter is made up of the following sections:

a. Low pass filter frequency determining network (plug-in).
b. Low frequency chopper stabilized DC amplifier.
c. Chopper drive, free running multivibrator.
d. High frequency DC amplifier.
e. Current limiter.
f. Voltage limiter.

All components with numbers in the 4600 series are the low pass tuning unit plug-in. The low pass filter cutoff frequency may be selected by changing the low pass plug-in to the desired information bandwidth. The output of the loop filter, isolated by the transistor Q3400 and Q3401, is connected to the input of the low pass filter (see Figure 4-13).

4-76. Signals in the frequency range of 0 to about 60 cycles are amplified by the chopper amplifier which consists of Q1619, Q1618, Q1617, Q1616, and Q1615. The chopper drive unit operates the transistor choppers Q1619 and Q1615. Q1619 is switched on and off at a 2 kHz rate producing a 2 kHz square wave that is amplitude and polarity dependent on the low pass filter input voltage level. This amplitude dependent square wave is amplified by transistors Q1618, Q1617, and Q1616. Q1615 chops the output of the amplifier to ground in alternate synchronism with Q1619. Thus, with a signal to the low frequency chopper stabilized amplifier as shown below:


(A) Q401 signal at base
(B) Q401 signal if the emitter of Q402 did not run into the base wave form
(C) Q402 signal at base
(D) When unit is locked
Q402 base
Q405 base
(E) When unit is out of lock
Q402 base
Q405 base

When proper phasing of the VCO and Limiter signal is selected and the unit is locked, the signal at the base of Q405 will be as indicated at (D). Q405 will not conduct until the base voltage becomes more positive than permitted by the emitter of Q402 (E).

Figure 4-12. Phase Comparator Waveforms

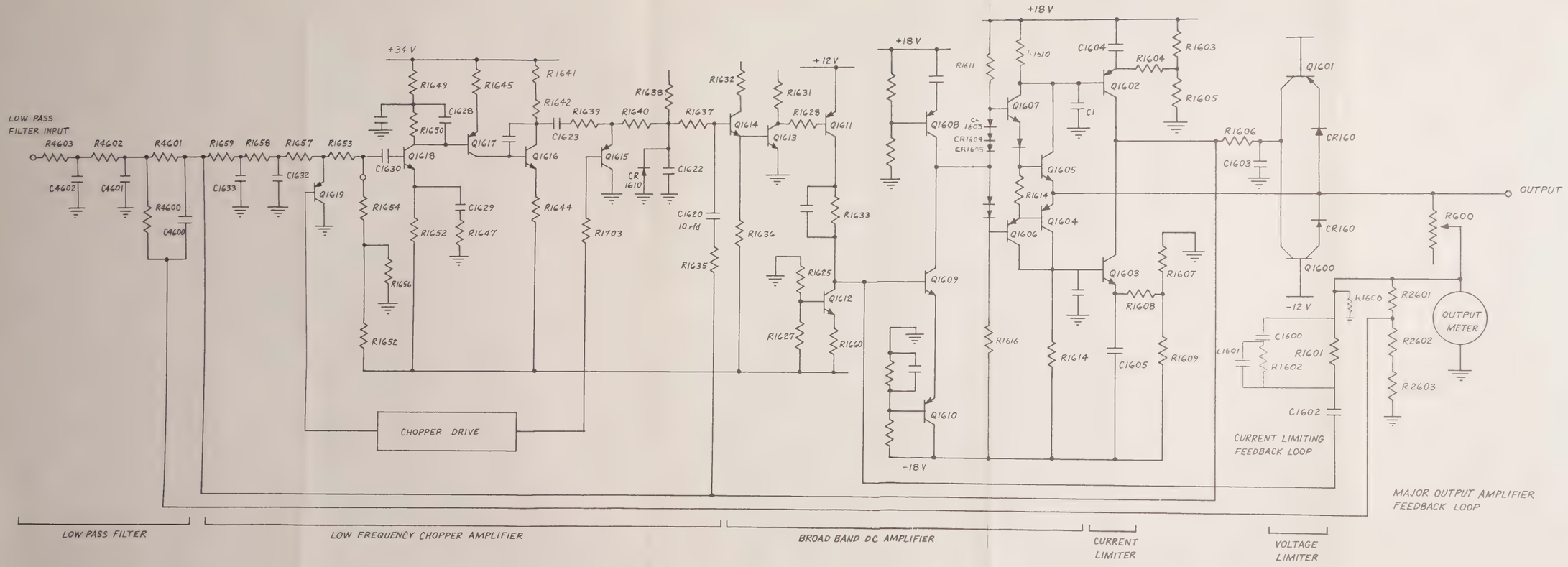
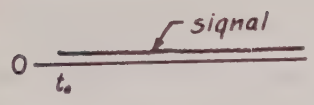


Figure 4-13. Broad Band DC Amplifier, Schematic

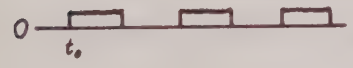
for plus input



for minus input

The signal on the emitter of the transistor chopper Q1619 would look as shown:

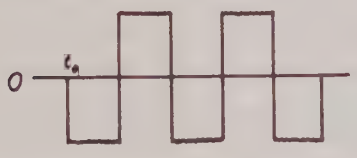
for plus input



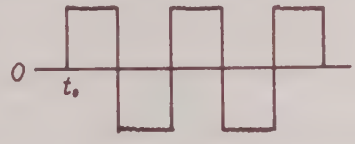
for minus input

The signal of the emitter of Q1615 if it were not operational:

for plus input



for minus input



The signal of the emitter of Q1615 when the chopper is operational:

for plus input

for minus input

As shown, the input signal to the low frequency chopper amplifier does not loose its polarity identify and is proportional to the input voltage. The chopper drive unit, utilizing transistors Q1700 and Q1701, is a free running multivibrator which generates the 2 kHz square waves to drive the chopper transistors Q1615 and Q1619.

4-77. The output signal from the narrow band chopper amplifier is connected to the broad-band DC amplifier. The input summing point of the broad DC amplifier is the base of Q1614. It should also be noted that the output of the frequency determining plug-in unit is connected both to the narrow band chopper amplifier and the broad band DC amplifier. Thus signals above 60 Hz are capacitively coupled directly from the output of the frequency determining plug-in unit through R1635 and C1620, to Q1614. It should be understood that the low frequency narrow band chopper amplifier is a low frequency booster whose gain adds to the low frequency gain of the DC amplifier.

4-78. The broad band DC amplifier provides the gain for an output of ±10 volts peak-to-peak maximum for full deviation with an output impedance of less than 0.1 ohm. Q1614 is an emitter-follower providing isolation for the summing point of the high and low frequency signals. Q1613 and Q1611 are current amplifiers which in conjunction with Q1609, a current to voltage conversion amplifier, provide the gain of the DC amplifier. Q1612 is a constant current source for the collector of Q1611 and , since the base of Q1609 is pegged by the emitter voltage, all the current change from Q1611 is fed to the base of Q1609. Q1608 is a current source for the collector of Q1609 providing a check on the current demands of the voltage amplifier Q1609.

4-79. The bias string, consisting of R1611, CR1603, CR1604, CR1605, CR1606, CR1607 and R1616 provides the operating bias for Q1606, Q1607, Q1604, Q1605 and also sets the collectors of Q1608 and Q1609 to zero volts under zero output conditions. The diodes, CR1603, CR1604, CR1605, CR1606 and CR1607, in addition to providing bias also provide a very low impedance coupling circuit from the voltage amplifier, Q1609, to the bases of the driver emitter-followers Q1606 and Q1607. In addition, CR1603, CR1604 and CR1605 provide temperature compensation for the diode junctions of Q1605, Q1607 and CR1602 while CR1606 and CR1607 match Q1604 and Q1606.

4-80. As mentioned, Q1606 and Q1607 are driver emitter-followers for the output power emitter-followers Q1604 and Q1605, respectively. The local feedback loop, consisting of R1601 and C1602, in conjunction with the output level control R600 and the feedback resistor R1600 provide a means of stabilizing and lowering the output impedance of the power emitter-followers. Since this local feedback loop encompasses the current to voltage amplifier Q1609 as well as the emitter-followers Q1604, Q1605, Q1606 and Q1607, the network consisting of R1602, C1600 and C1601 provides the frequency control necessary to prevent oscillations in the output stages. The remaining frequency control networks, consisting of R1629 and C1613 and C1618, provide the main control for the amplifier frequency response.

4-81. Output voltage limiting is accomplished by a diode network consisting of CR1615, CR1616, CR1617 and CR1618. It senses the output voltage and clamps the input voltage when the output reaches a predetermined level. Ordinarily CR1615 and CR1616 are conducting. Since CR1617 and CR1618 are connected to the amplifier error point which is always at very nearly zero volts, they are biased off by the contact potential of CR1615

and CR1616. When the output voltage reaches approximately +13 volts, CR1615 turns off and CR1618 turns on and clamps the input voltage. Similar action accurs when the output voltage reaches -13 volts.

4-82. Output current limiting is accomplished by transistors Q1602 and Q1603. They sense the output current flowing through the output emitter-followers and feed a current into the input which holds the output current to a predetermined level. The base of Q1602 is tied to the collector of Q1605 and the base of Q1603 is tied to the collector of Q1604. Transistor Q1602 is biased off by the bias divider network R1603, R1604 and R1605. As the output current through Q1605 increases, the voltage drop across R1610 increases until the bias point of Q1602 is reached and Q1602 starts conducting. Since the collector of Q1602 is tied to the amplifier error point, the current that flows through Q1602 also flows through the amplifier error point in the correct phase to turn the output current down which stabilizes the output current to the predetermined level of 150 milliamps, maximum. Similar action occurs during the time when Q1604 is conducting and Q1603 is turned on.

4-83. POWER SUPPLY. The demodulator circuits require six supply voltages, -50 V, -18 V, -12 V, +12 V, +18 V, and +34 V. Because high gain direct coupled circuits are used throughout, the required voltages must be regulated precisely to minimize drift and offset. The demodulator output power amplifier operates from unregulated sources of +18 and -18 volts. Each voltage source is obtained from a common power transformer having several taps on its secondary winding. The well regulated +34 volt supply is used as the voltage reference for the -12 volt and the -50 volt supplies. In turn the -50 volt supply is used as a reference for the +12 volt supply; thus proper operation of the three supplies are dependent upon the +34 volt supply.

4-84. ADJUSTABLE LOOP FILTER, GFD-13/TUA.

4-85. The phase-locked loop is basically an auto-correlation method of frequency discrimination. A block diagram of the total demodulator and of the demodulator proper (demodulation phase-locked loop) is shown in Figure 4-2. The input subcarrier waveform is shaped and fed into the phase comparator. The internal voltage controlled oscillator (VCO) is also fed into the phase comparator. When the loop is locked, the VCO frequency is the same as the subcarrier input frequency and the comparator has an average voltage output proportional to difference in phase between the input subcarrier and VCO output.

4-86. This voltage is fed, through the loop filter, back to the VCO in order to reduce the phase difference between the two signals and keep the loop locked. The loop filter restricts the frequency response of the loop, keeps the loop from oscillating, and reduces the noise bandwidth into the VCO. This noise difference is made up by jitter in the phase sensitive demodulator referred to as "phase jitter".

4-87. If both the source of the input subcarrier and the internal VCO have frequency outputs linearly related to voltage inputs, these voltages will be essentially proportional. This input to the local VCO is therefore the discriminator output. However, some of the noise picked up in transmission is filtered out by the loop filter. The amount of noise filtered out depends on the loop filter modulation index. The remaining phase sensitive demodulator by-products are filtered out with a low pass output filter which is fed from the same point as the VCO input.

The classical definition of modulation index is

$$MI = \frac{\text{Deviation}}{\text{Intelligence frequency}}$$

In this discussion, the maximum modulation is commonly referred to, and the loop modulation index

$$MI_{Loop} = \frac{\text{Maximum Channel Deviation}}{\text{Loop Filter Cutoff Frequency}}$$

This should not be confused with Channel Modulation Index as referred to in IRIG specifications which is

$$MI_{Channel} = \frac{\text{Maximum Channel Deviation}}{\text{Low Pass Output Filter Cutoff Frequency}}$$

4-88. A price must be paid in order to filter the transmission noise. As the noise bandwidth is reduced, the phase-locked loop demodulator information frequency capability is likewise reduced. Moreover, as the loop filter modulation index increases, the frequency capability for full bandwidth deviation decreases even more rapidly than the loop filter cutoff frequency. These effects are inherent in any properly designed phase-locked loop, regardless of circuitry. For optimum results with an adjustable loop filter, the operator must both fully understand the phase-locked loop, the specific circuitry involved, and must also develop a good laboratory technique with the equipment. An idea of the characteristics

of the specific data-noise signal to be measured and which part of this data is to be recovered for analyzing is also necessary.

4-89. The VCO, regardless of channel deviation, takes ±2.5 volts to deviate full bandwidth. Figure 4-2 shows the connection of the loop filter in the circuit and after loop filter cutoff is passed, the output of the phase sensitive demodulator is attenuated at the input to the VCO. The phase sensitive demodulator must then deliver much more than ±2.5 volts to the loop filter in order to deviate the VCO full bandwidth. Since the loop filter is in a closed loop circuit, there is no reason to think that the voltage limitation of the loop filter on the full bandwidth deviation of the loop is the same as the frequency pass band. In fact, this is not the case and the maximum full bandwidth deviation without loss of lock is approximately one over the square of the modulation index times the cutoff frequency for a modulation index of 1, while the cutoff frequency is one over the modulation index times the cutoff frequency for a modulation index of 1. For instance, in the IRIG Band 18, with a loop filter calculated on the basis of a development by Gruen,

$$f_c \Big|_{MI = 1} = 5250 \text{ cps}$$

$$f_c \Big|_{MI = 10} = 525 \text{ cps}$$

On the basis of our approximation, Maximum Frequency of Full Bandwidth Deviation is approximately 52.5 cps. Actual measurement is 86 cps. This is inherent in any correctly designed loop filter and any effort to increase the loop gain in order to improve this situation only changes the loop filter components for the same loop noise bandwidth and results in no improvement.

4-90. One factor of importance is to have a small static (DC) phase error necessary to deviate to bandedge (statically). This same small static phase error in the phase demodulator must be maintained as the modulation index is increased. This allows the ±90° maximum phase error to be used mostly for dynamic data and prevents the above mentioned loss of lock as long as possible. This characteristic is part of a correctly designed loop.

4-91. How do these considerations affect the use of the adjustable loop filter? The standard tuning unit is designed with a loop filter modulation index of 1. This loop filter will stand a full bandwidth step in frequency, within the band, without losing lock, and is the smallest

modulation index necessary. With the loop filter switched to 100% NB and the phase error centered, the GFD-13/TUA is identical to the GFD-13/TU. The noise bandwidth is wide. Decreasing the noise bandwidth also increases the chance of loss of lock. This loss is dependent on the rate of change of voltage out of the phase demodulator. When the phase error necessary to charge the loop filter and move the VCO at the proper rate exceeds 90°, the phase demodulator cannot deliver the required voltage and the loop loses lock. The rate required is interdependent on the information frequency, information amplitude, noise frequency and noise amplitude. Reducing any one allows the other three to increase in any proportion as long as the total requirement is less than or equal to before. Phase error should be adjusted so that the chance of losing lock is equal on both sides. This allows the maximum amount of noise to be tolerated. The phase adjustment in conjunction with the input meter as an average phase indicator is used for this purpose. The noise bandwidth can then be narrowed as much as possible with the % Noise Bandwidth switch. This narrowing is limited by the maximum intelligence frequency and amplitude, and noise frequency and amplitude passed by the band pass filter and broad band limiter.

4-92. Information to be measured or recorded for analysis is not dependent on the above. The maximum frequency to be presented flat to the low pass output filter is determined by the loop filter cutoff frequency. A low pass filter with any cutoff frequency lower can be used to filter out both higher frequency intelligence that may not be desired in a particular analysis and the noise in the same band. To be sure, this will not have any effect on the locking or thresholding of the discriminator, but it will add to the clarity of the data.

4-93. The phase-locked loop is a powerful tool that, if used correctly, can give results comparable with other types of discriminators with a 28 db worse signal to noise ratio at high modulation indexes. Correct choice of low pass filters cannot improve the threshold but can present the data with an even better overall input noise to output noise ratio and can be used to select specific bands of data from the total information signal. Table 4-1 is typical of adjustable loop filter operation. Loop filters are calculated with a damping factor of .7 and the cutoff frequencies,which are the results of the calculations, are related to the noise bandwidth and are not the 3 db down points. Since the loop will not lose lock at a modulation index = 1 and a safety margin is included, the square approximation for full bandwidth is pessimistic at low modulation indexes. At high modulation indexes, it is more realistic. Values in the table for Maximum Full Bandwidth Deviation are measured.

Table 4-1. Typical Channel Characteristics

Channel 70 kHz ±7.5% IRIG Band #18			
Loop MI	% Noise Bandwidth	Loop Filter Cutoff Freq. (Hz)	Maximum Frequency for Full Bandwidth Deviation (Hz)
1	100	5250	Does not lose lock
3	75	1750	1350
5	50	1050	410
10	30	525	86
20	15	175	9
50	7	105	2.6

4-94. TAPE SPEED COMPENSATION.

4-95. The multiplex of subcarrier signals from the FM receiver may be recorded on magnetic tape for future study. When the tape is played back, any variation in tape speed will show up as variations in the subcarrier frequencies with corresponding variations in demodulator output voltages. When precise measurements are required, the system may be compensated for tape speed variations as shown in Figure 4-14. When tape speed compensation is required, a constant frequency reference signal must be recorded on the tape along with the subcarriers. A typical frequency is 100 kHz.

4-96. The tape recorder output is distributed to the data demodulator and through a GFD-13/RTU Reference Demodulator. A GFD-13/RTU Reference Demodulator consists of a standard GFD-13 demodulator with a special tuning unit whose band pass filter selects the reference signal frequency. The output voltage from this demodulator, therefore, is proportional to the deviation of the tape speed from its nominal value.

4-97. Since the reference signal is delayed in passing through the filters of the reference demodulator, the subcarriers must be delayed an equal amount of time for proper tape speed compensation. The GFD-13/RTU unit provides the time delay required for the subcarriers.

4-98. The output voltage from the reference demodulator, which is proportional to the tape speed error, is connected to the voltage controlled oscillator in each data demodulator. For example, if the tape slows down, the frequency of each subcarrier drops proportionally, and without compensation each demodulator output voltage would change accordingly. But the speed

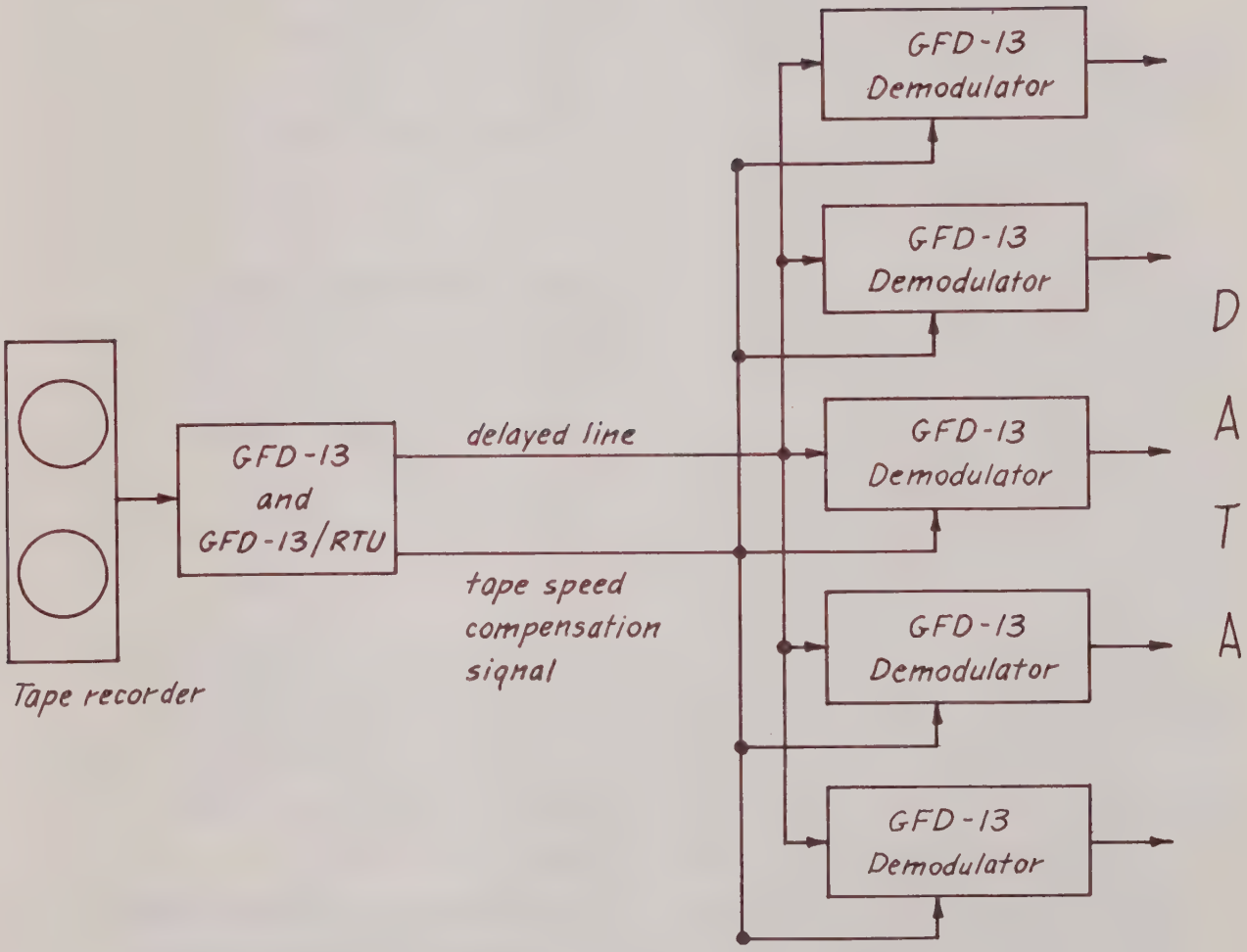


Figure 4-14. Tape Speed Compensation

compensating signal connected from the reference demodulator to the VCO in each data demodulator tends to reduce each VCO frequency. In each data demodulator, in order for the phase-locked loop to remain locked, the VCO frequency control voltage must change so that it corresponds to a higher frequency. (Recall that the VCO frequency control voltage is equivalent to the demodulator output.) With proper action of the compensating circuit, the VCO frequency control voltage and the corresponding demodulator output voltage can be restored to the value it would have been in the absence of tape speed variation.

SECTION V

MAINTENANCE

5-1. GENERAL.

5-2. This section covers the preventive maintenance for proper performance of the equipment. Acceptable performance is defined within the limits of the performance test described herein. Troubleshooting and location of components is included.

5-3. TEST EQUIPMENT. Test equipment is listed in Table 5-1.

Table 5-1. Test Equipment

Nomenclature	Characteristics
FM Oscillator	DCS Model GOV-3, GSO-1 or equivalent
RMS VTVM	Hewlett-Packard 400D or equivalent
VTVM	RCA Senior Voltohmyst or equivalent
Electronic Counter	Hewlett-Packard 522B or equivalent
100 ohm, 10 watt load resistor 100 ohm, 2 watt load resistor Current Meter	Simpson 260 or equivalent

5-4. PREVENTIVE MAINTENANCE.

5-5. VISUAL INSPECTION. Inspect the front panel and cover for physical signs of damage which might occur during shipment.

5-6. WEEKLY INSPECTION. A visual inspection should be made at least once a week, during which the following items are checked:

a. Adequacy of cooling air supply.

b. Evidence of overheating.

c. Loose or defective wiring.

d. Loose component and subassemblies.

5-7. SEMI-ANNUAL INSPECTION. When a demodulator is first installed and at least once every six months thereafter, the following items should be checked:

a. Adequacy of cooling air supply.

b. Evidence of overheating.

c. Loose or defective wiring.

d. Loose components and subassemblies.

e. Evidence of overheating on each printed circuit board.

f. Excessive noise generation by the chopper.

g. Waveforms.

h. Power supply voltages*.

i. Performance test.

*Because direct coupled amplifiers are used through the demodulator its operation depends entirely upon how well the power supply voltages are maintained at their original values. A small change in a supply voltage can cause considerable zero offset and subsequent saturating or clipping action in a high gain d-c amplifier. It is recommended that when the demodulator is first installed, its supply voltages be measured with a high-precision voltmeter and the data be recorded for future reference. If the voltages ever deviate from these values, it can be assumed that the demodulator performance will deteriorate, and that repair is necessary. (See Figure 5-1 below.) Critical voltage at the 35 V terminal should be adjusted to 33.3 V by trimpot R2819.

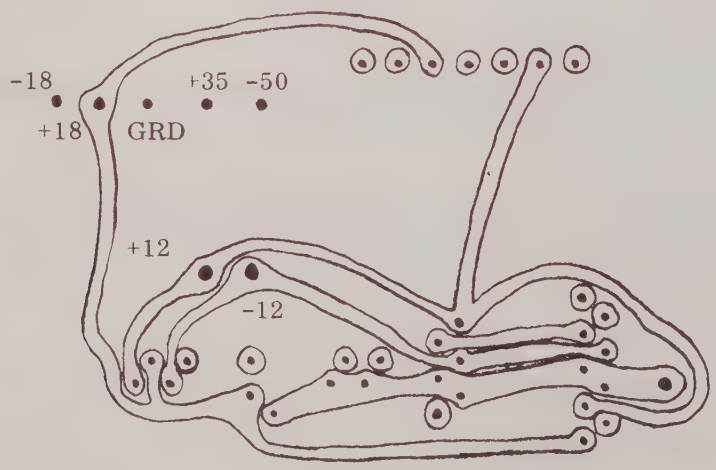


Figure 5-1. Location of DC Voltages on Main Connector Board

5-8. PERFORMANCE TEST. The tests described herein are the minimum tests required to ensure proper performance of the equipment. If equipment does not comply with minimum performance the cause must be determined through the maintenance procedure.

a. Connect an FM oscillator to the demodulator input. Arrange the rms VTVM to measure the amplitude of the input signal and the electronic counter to measure the frequency of the input signal.

b. Connect the load resistor to the demodulator output. Arrange the peak-reading VTVM and d-c VTVM to measure the demodulator output voltage.

c. Set the oscillator exactly at the center frequency of the band pass filter and the output level control at 10 volts. After at least a 15 minute warmup period, make the band centering adjustment.

d. Check the zero adjustment of the output level meter. It should indicate zero when the demodulator output voltage is zero.

e. Check the operation of the input signal level meter. With an input amplitude of 10 millivolts rms, the meter should indicate half scale on the 20 millivolt rms range. When the input amplitude increases to 1 volt rms, the meter should indicate half scale on the 2 volt rms range.

f. Check the limiter sensitivity. A 20 db change in input amplitude (amplitude change by factor of 10) should not cause a change in the demodulator output voltage greater than 0.3% of bandedge output (±.03 VDC), with carrier at band center and a low pass filter designed for a modulation index of 5.0. Repeat the test at the upper and lower bandedges.

g. Check calibration of the output level control with the oscillator set at bandedge frequency. With the oscillator set a bandedge frequency and the output level control at 10 volts, the demodulator output voltage should be 10.3 VDC ±1%.

h. At bandedge, reduce the input amplitude below 1 millivolt rms. The output voltage should fall to approximately zero.

i. Check the output voltage limiter operation. Set the input amplitude at 2 volts rms and the output level control at maximum. Any variation in input frequency should not cause the output voltage to exceed ±13 VDC.

j. Check the output current limiter operation. Set the input amplitude at 2 volts rms, the input frequency at bandedge and the output level control at maximum.

Set Simpson 260 to d-c current 500 ma scale and connect in series with 100 ohm load. Paralleling 100 ohm load with another 100 ohm resistor should cause an increase in current which is limited to 150 ma.

k. Check the overall frequency response. Set the oscillator at band center frequency at 2 volts rms. Frequency modulate the input signal at maximum deviation (±7.5% for bands 1 through 21 and ±15% for bands A through H). Measure and plot the demodulator output voltage amplitude, as indicated by the peak-reading low frequency VTVM, as a function of the frequency of modulation. As the modulating frequency approaches the cutoff frequency of the low pass filter, using a cutoff frequency corresponding to a modulation index of 5, the output amplitude should fall approximately 3 db below its low frequency value.

l. Note that the maximum carrier frequency deviation which can be accommodated depends upon the loop filter. The standard loop filter can accommodate a full bandwidth step change in carrier frequency. The switchable loop filter bandwidth depends upon the setting of its selector switch. Hence, during the performance tests, the input signal maximum frequency deviation, and maximum modulation frequency should be chosen to suit the particular tuning unit.

5-9. TROUBLESHOOTING.

5-10. GENERAL. Find whether the malfunction is caused by a failure of the demodulator itself or by an external failure. Check the incoming signal to the demodulator and the load circuit connected to the demodulator output. If the demodulator itself appears to be at fault, first try changing the plug-in units including the low pass filter and band pass filter units. If the preliminary checks and substitutions indicate that the failure is in the demodulator main section or power supply rear section, remove the entire unit from its housing and inspect it for visible signs of failure, such as burned resistors, etc. When such a fault is located, always test other components in the same circuit to see whether a hidden failure caused the obvious failure. A typical example of this situation occurs in a common-emitter amplifier in which the emitter bypass capacitor develops a short circuit which is not visible. In turn, this causes excessive collector current which may burn out the collector load resistor -- a visible indication of failure. If the shorted capacitor is not discovered and replaced, a new collector load resistor will also burn out.

5-11. TEST PROCEDURE. Assemble a cable with a spare input-output connector so that the demodulator may be supplied with a-c power, an input signal, and an output load while on the bench. Be sure to make the necessary jumper connections at the S1 socket (see Tables 2-1 and 2-2 in Section II).

5-12. Turn on the a-c power and check each power supply output voltage with a precision voltmeter having an accuracy of 0.5% or better. Compare the readings with those obtained during routine maintenance. If they differ, troubleshoot the power supply or look for excessive loading caused by a failure in the demodulator. Remember that the power supply voltages are interdependent, and are referred to the +35 volt supply. By adjusting the +35 volt supply the other supply voltages are also adjusted. DO NOT attempt to adjust the supply voltages unless a component in the +35 volt supply has been replaced (because of failure) whose new value changes the voltage(s). Then the voltage must be set exactly at 33.3 volts.

5-13. The easiest way to isolate a fault is to trace the progress of a signal through the demodulator from input to output, using an oscilloscope. For this purpose, supply the demodulator with an input signal at the band pass filter center frequency. If possible, use an oscillator which permits frequency modulation of the subcarrier input signal. Data-Control Systems, Models GOV-3 or GSO-1 Voltage Controlled Oscillators, are particularly adaptable. Refer to drawing EW-013819, Table 5-2 and Figure 5-2 which show typical waveforms at significant test points in the circuit and the conditions for obtaining each. By comparing the performance of the demodulator to these waveforms, it is usually possible to isolate the particular circuit in which the failure has occurred.

5-14. If possible, replace the particular circuit board on which the failure is located. Otherwise troubleshoot the circuit board to find the faulty component. New type transistors are being manufactured which differ from one another in respect to their base-emitter-collector terminals. Figure 5-3 illustrates the base-emitter-collector terminal positions for different types of transistors used in the GFD-13.

5-15. LOCATION OF COMPONENTS. Individual printed circuit boards are used for various circuits and portions of circuits. The components on each board are identified by different series of reference numbers described in Table 5-3. The same series of reference numbers

Table 5-2. Test Points (referenced to Figure 5-2 and schematic drawing EW-013819)

Test Point	Board	Location
1	Limiter Board	Input to 1st Limiter (CTC lug two wires)
2	Limiter Board	Output of 1st Limiter (Link to C210)
3	Limiter Board	Output of 2nd Limiter (Link to Q206)
4	Limiter Board	Input to 3rd Limiter (CTC lug after R226)
5	3rd Limiter Demod. Bd.	Input to 3rd Limiter (back CTC lug to R300)
6	3rd Limiter Demod. Bd.	Limiter feedback (front CTC lug to R302)
7	3rd Limiter Demod. Bd.	Output of 3rd Limiter (link to P.C. to C402, C401)
8	Phase Comparator Demodulator Board	P.C. Signal Input (CR404 at Q412 emitter)
9	Phase Comparator Demodulator Board	P.C. Signal Input (CR405 at Q413 emitter)
10	Phase Comparator Demodulator Board	P.C. Signal End (To collector Q414) junction of CR404, CR405
11	Phase Comparator Demodulator Board	P.C. VCO Input, CR400 at Q408 emitter
12	Phase Comparator Demodulator Board	P.C. VCO Input, CR401 at Q409 emitter
13	Phase Comparator Demodulator Board	Phase Comparator Output (CTC lug of 50S cable)
14	Phase Comparator Demodulator Board	Delta Phase Output (CTC lug of 50Z cable)
15	Demodulator Board Lock Light	Lock Light Input (junction of R408, R407)
16	Demodulator Board Lock Light	No-lock light VCO input (junction of R402, C403)
17	Demodulator Board Lock Light	No-lock light lamp driver (base of Q406)
18	Blank	
19	Blank	
20	Demodulator Board VCO	VCO output (link to P.C.)
21	Demodulator Board VCO	VCO output (VCO link)

Table 5-2. Test Points (referenced to Figure 5-2 and schematic drawing EW-013819) (continued)

Test Point	Board	Location
22	Demodulator Board VCO	VCO Timing Wave (CR500 or 50H cable)
23	Demodulator Board VCO	VCO Timing Wave (CR501 or 50M cable)
24	Demodulator Board VCO	Loop filter output (Q524 base, back CTC or 50K cable)
25	Demodulator Board VCO	Loop filter output (deviation) (Q523 base, front CTC or 50E cable)
26	Demodulator Board VCO	VCO Darlington input (VCO side)
27	Demodulator Board VCO	VCO Collector Load (junction of R507, R509)
28	Demodulator Board VCO	VCO Collector Load (junction of R518, R510)
29	Demodulator Board VCO	VCO Feedback (junction of R524, R526)
30	Demodulator Board VCO	VCO Feedback (junction of R501, R500)
31	Demodulator Board VCO	VCO Feedback (junction of R516, emitter of Q517)
32	Demodulator Board VCO	VCO Feedback (junction of R502, emitter of Q500)
33	Demodulator Board VCO	VCO Feedback (junction of R515, emitter of Q516)
34	Demodulator Board VCO	VCO Feedback (junction of R503, emitter of Q501)
35	Demodulator Board VCO	VCO Darlington Amp. (R514, CTC lug 50P)
36	Demodulator Board VCO	VCO Darlington Amp. (R504, CTC lug 50B)
37		LPA chopper output at junction of R1639 and R1640

are used to identify the individual terminals of each printed circuit board connector. For example, the components associated with the low pass filter are mounted on one board on which all components are identified by numbers beginning with 4600 and whose connector terminals are identified with numbers beginning with 4600. On each board, the terminal numbers increase to the right when the board is held component side up with the connector pins toward the observer.

All Test Points taken with:
Channel 18
1.05 L.P. output filter
Input - 1 V rms, H.P. osc. C.F.
Tektronix RM31A/Type H Plug-in
X10 probe
(Reference Table 5-2 and drawing EW-013819)

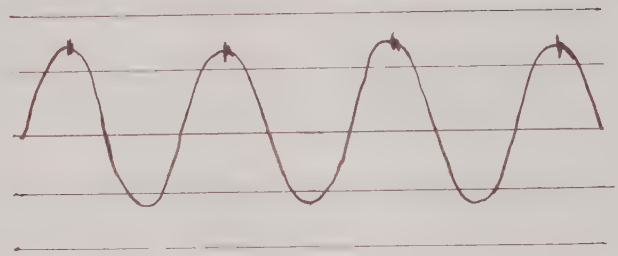
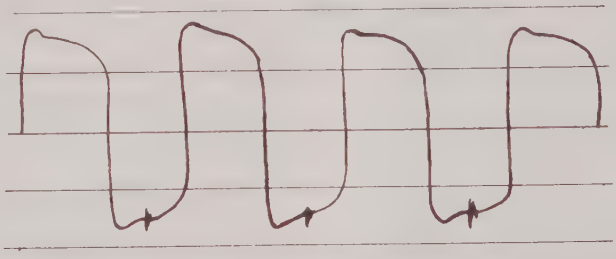
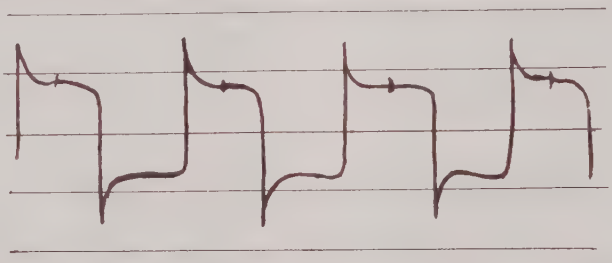
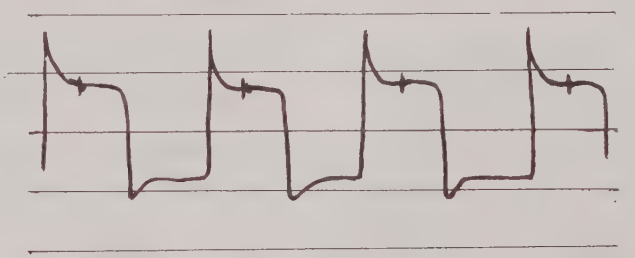
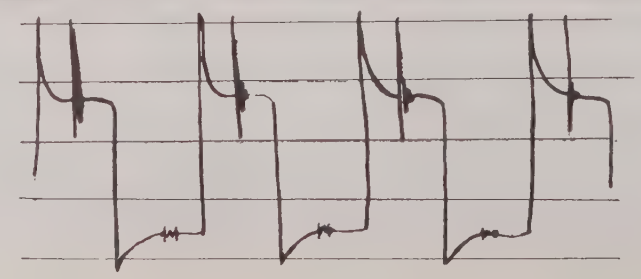
Test Point	Waveform	Oscilloscope Setting
1		0.1 V/CM 5 usec
2		0.05 V/CM 5 usec
3		0.1 V/CM 5 usec
4 , 5		0.05 V/CM 5 usec
6		.005 V/CM 5 usec

Figure 5-2. Waveforms

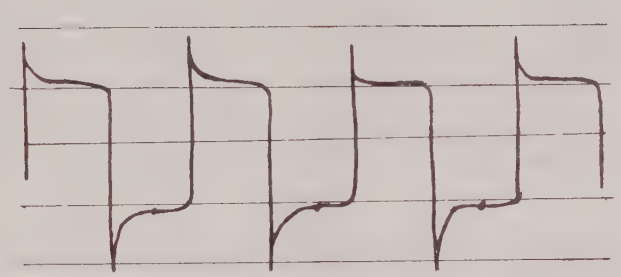
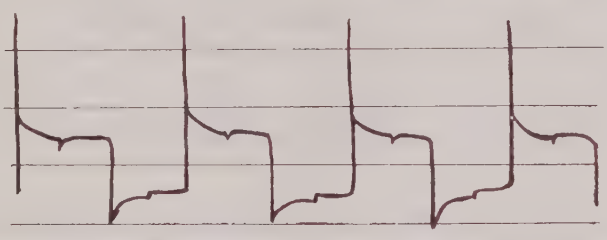
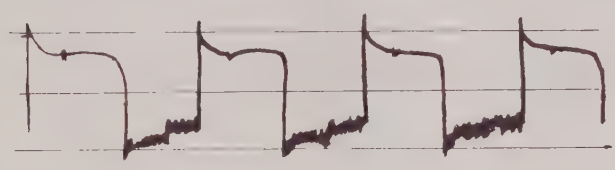
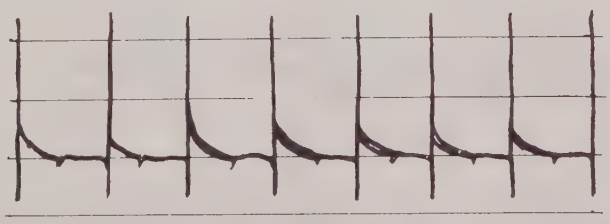
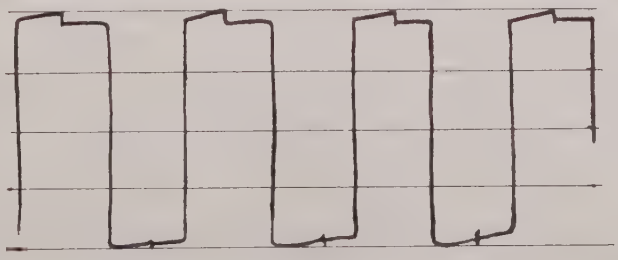
Test Point	Waveform	Oscilloscope Setting
7 , 15		0.2 V/CM 5 usec
8		0.2 V/CM 5 usec
9		0.2 V/CM 5 usec
10		0.2 V/CM 5 usec
11 , 12		0.2 V/CM 5 usec

Figure 5-2. Waveforms (continued)

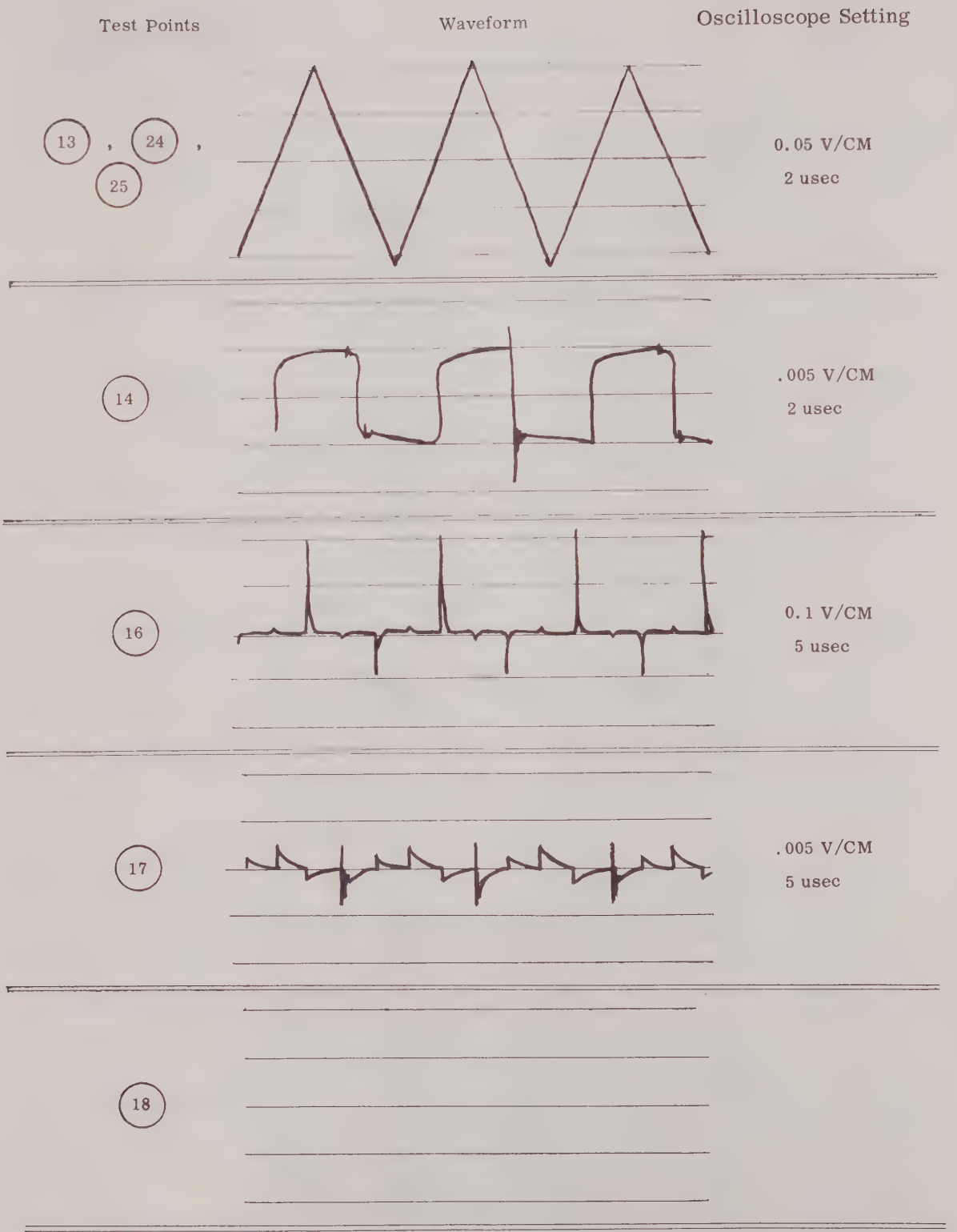


Figure 5-2. Waveforms (continued)

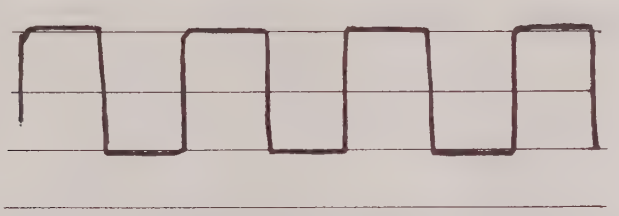
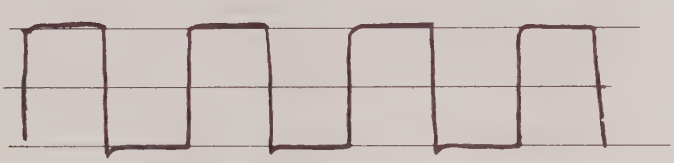
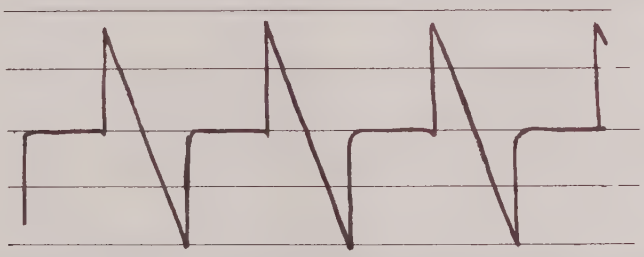
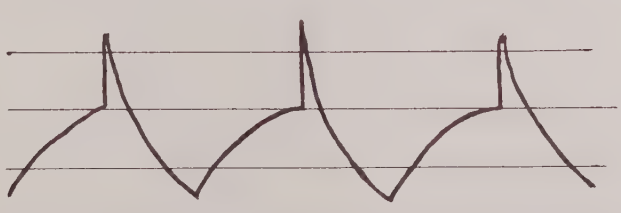
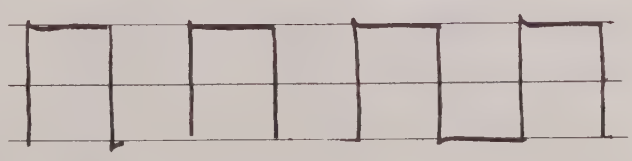
Test Point	Waveform	Oscilloscope Setting
20		0.5 V/CM 5 usec
21		0.5 V/CM 5 usec
22 , 23		0.5 V/CM 5 usec
26		0.1 V/CM 2 usec
27 , 28		0.1 V/CM 5 usec

Figure 5-2. Waveforms (continued)

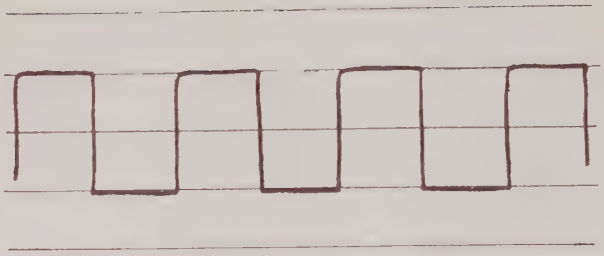
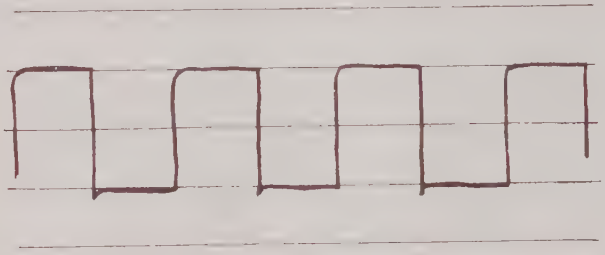
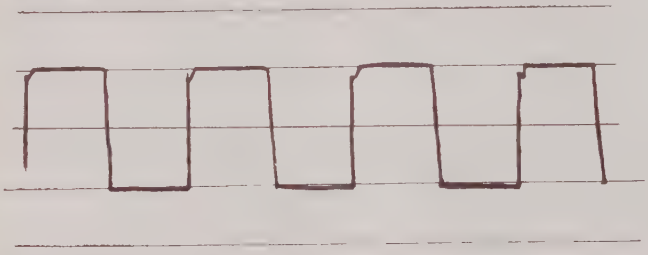
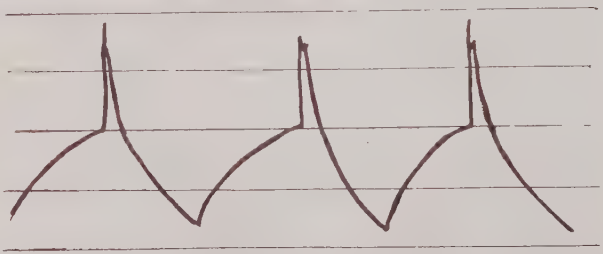
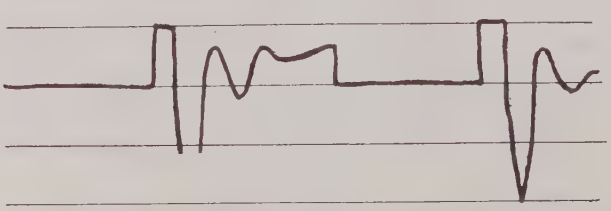
Test Point	Waveform	Oscilloscope Setting
29 , 30		0.5 V/CM 5 usec
31 , 32		0.5 V/CM 5 usec
33 , 34		0.5 V/CM 5 usec
35 , 36		0.1 V/CM 2 usec
37		0.1 V/CM 0.1 msec

Figure 5-2. Waveforms (continued)

All components are viewed from the bottom.

1st and 2nd Limiter

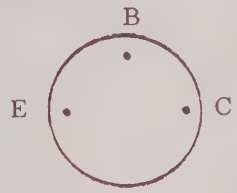
16L64 or 2N3855-A

Q200	Q204
Q201	Q205
Q202	Q206
Q203	Q207
Q208	

Upper Chopper

2N3012

Q1701
Q1700



VCO

16L64 or 2N3855-A

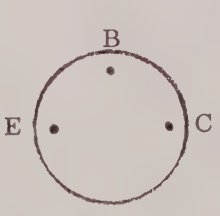
Q411	Q508	Q412
Q413	Q502	Q404
Q403	Q507	Q409
Q303	Q501	Q510
Q304	Q500	Q514
Q517	Q503	Q513
Q511	Q520	Q504
Q512	Q300	Q525
Q301	Q302	Q507
Q516	Q414	
Q515	Q408	

2N3391-A

Q406
Q400
Q405

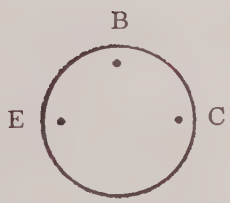
MM999

Q402 Q401
Q407 Q518
Q519 Q524
Q523 Q505
Q506



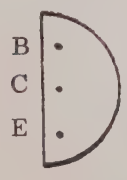
2N3638

Q527
Q526



2N3855-A

Q529
Q528



TIS03 - 2N3702

Q501
Q522

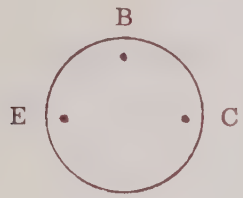
Figure 5-3. Location of Emitter-Base-Collector Terminals

All components are viewed from the bottom.

Output Amplifier

TN53

Q1603
Q1609

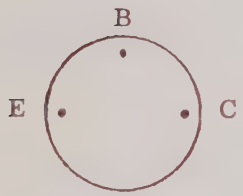


2N3391-A

Q1613
Q1614
Q1600

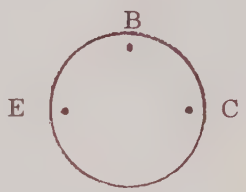
2N3133

Q1604
Q1602



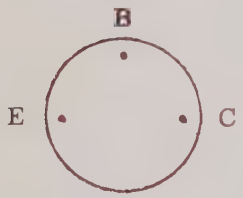
2N2218

Q1605



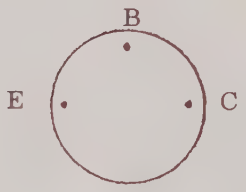
2N3638

Q1610
Q1617
Q1611



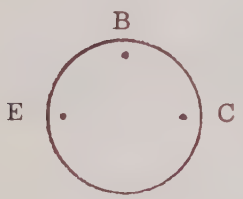
2N2280

Q1615
Q1619



MM999

Q1606
Q1608
Q1601



2N2716

Q1616

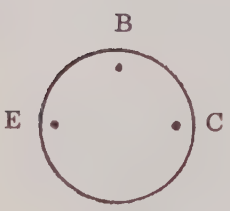
16L64 or 2N3855-A

Q1607
Q1612

Power Supply 2800

2N3638

Q2803 Q2814
Q2805 Q2813
Q2806 Q2815
Q2808 Q2816



2N3391-A

Q2802 Q2809
Q2804 Q2810
Q2809 Q2811

TN53

Q2801

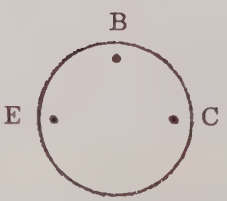


Figure 5-3. Location of Emitter-Base-Collector Terminals (continued)

Table 5-3. Subassembly Numbering System

Subassembly	Identification Numbers begin with:
1st & 2nd Limiter - Level input switch and Meter	200
3rd Limiter	300
Phase Splitter & Demodulator	400
VCO	500
Output Potentiometer & Meter	600
DC Amplifier & Power Output	1600
Chopper Drive	1700
Output Connector Board	2600
Power Supply	2800
+18 Volt Card	2900
Band Pass Filter	3100
Loop Filter and VCO Plug Card	3400 and 3500
Low Pass Filter Plug-in	4600

5-16. REPAIR. Be sure to observe the usual precautions when making repairs. Observe polarity markings on electrolytic capacitors and on diodes. Do not use more heat than absolutely necessary when soldering on the printed circuit wiring. If it is necessary to disconnect a transistor or diode lead or to replace any semi-conductor, always hold the component lead with pliers between the component body and the heated joint while soldering, so that the heat of soldering is drawn away from the semi-conductor. Remove excess solder flux. Make sure that all circuit boards are firmly seated and that all interconnecting terminals are properly mated.

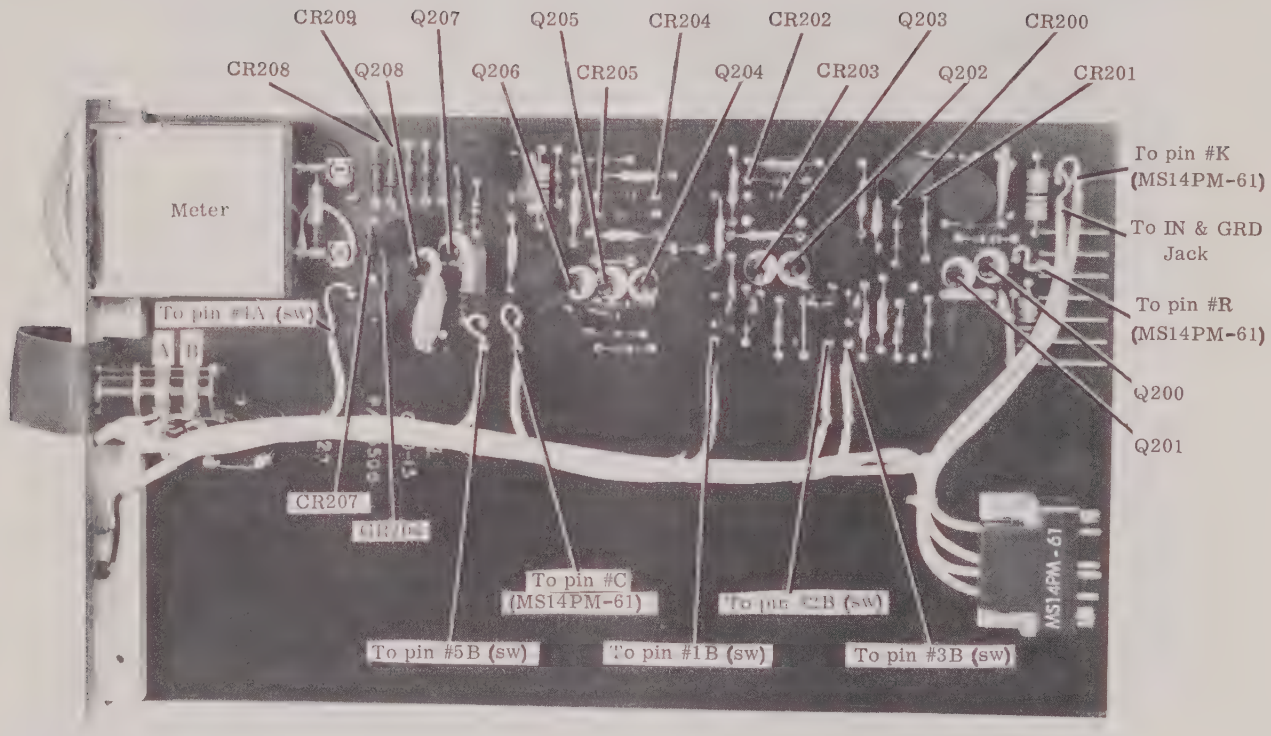


Figure 5-4. Limiter Board Assembly

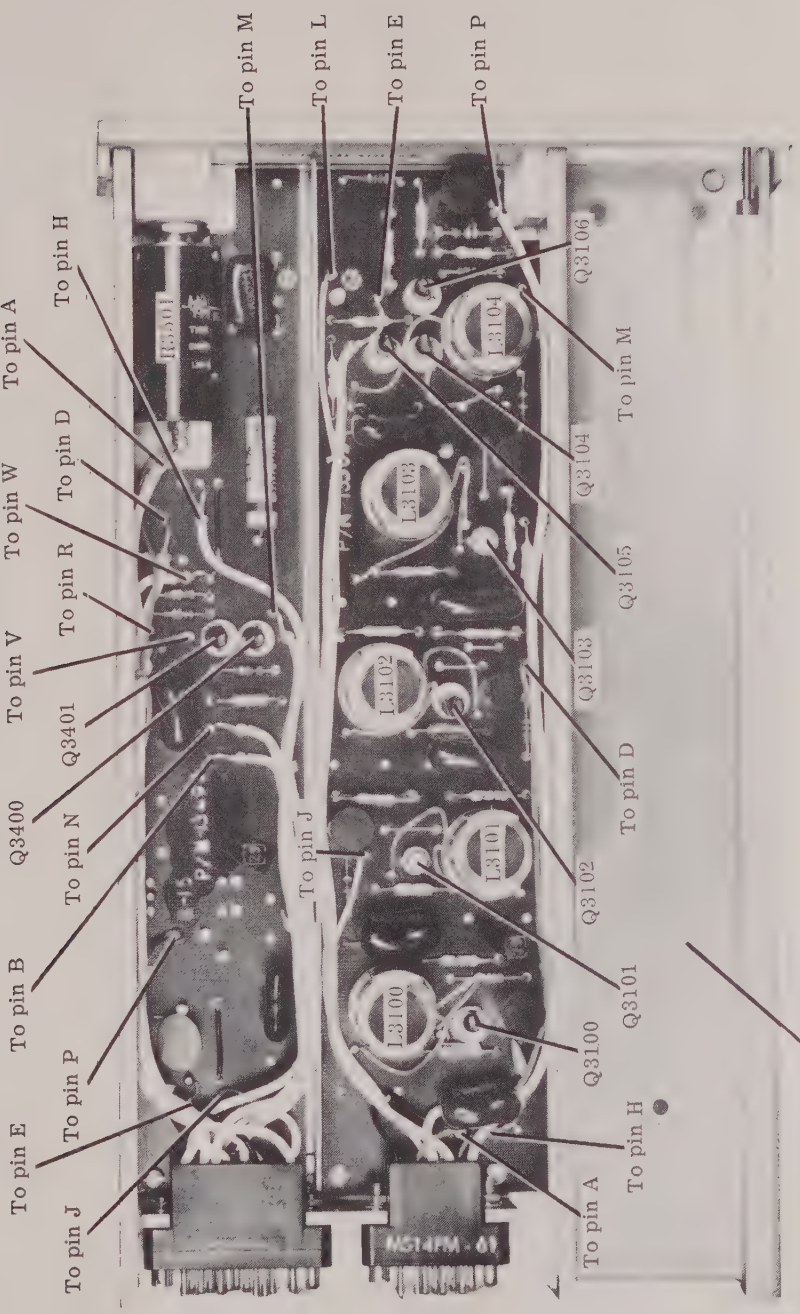


Figure 5-5. Tuning Unit Assembly (Band Pass, Loop Filter and VCO Low Pass)

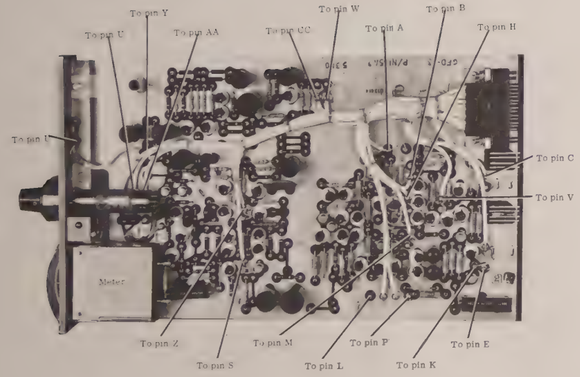
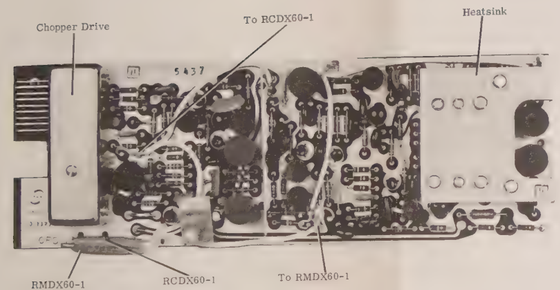
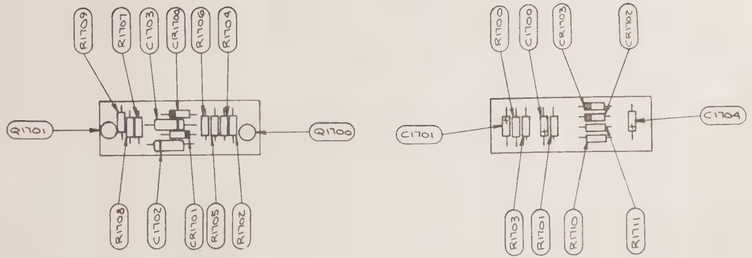
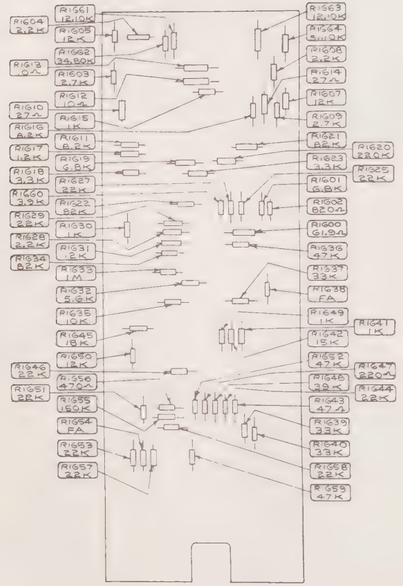


Figure 5-6. VCO Board Assembly (3rd Limiter, Phase Splitter and Demodulator)







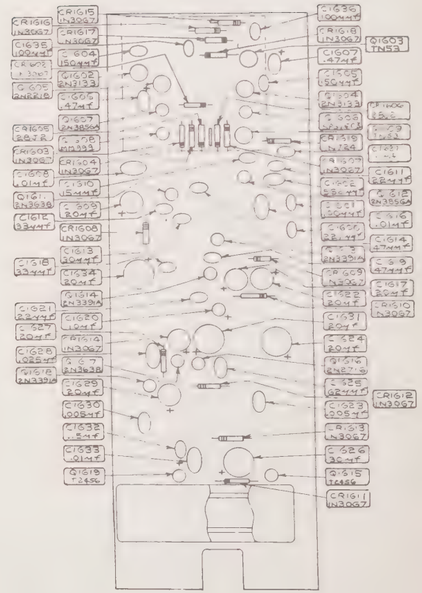


Figure 5-7. DC Amplifier and Power Output Board Assembly

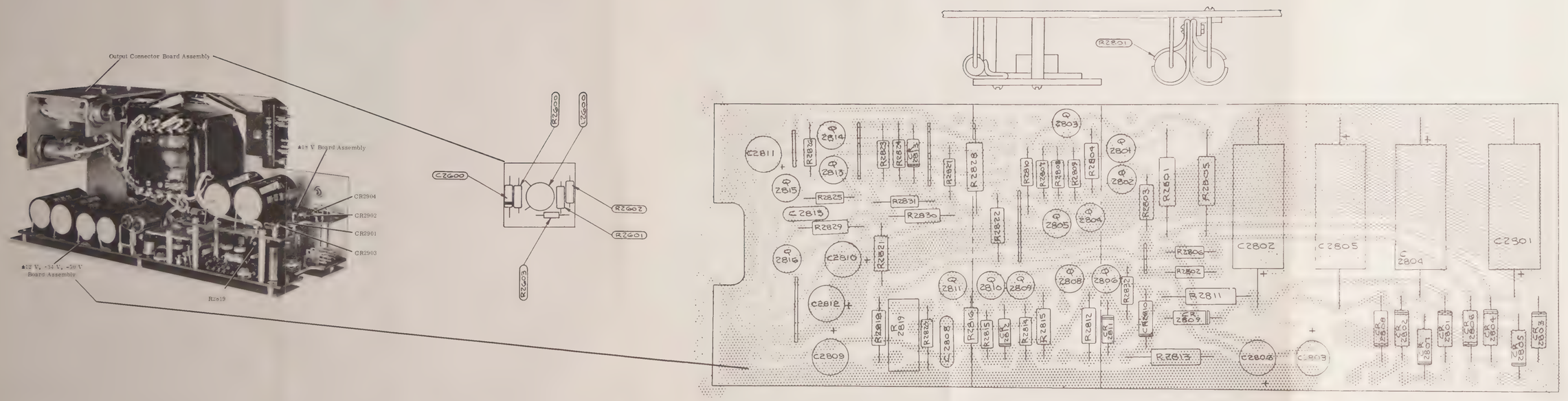


Figure 5-8. Power Supply Section

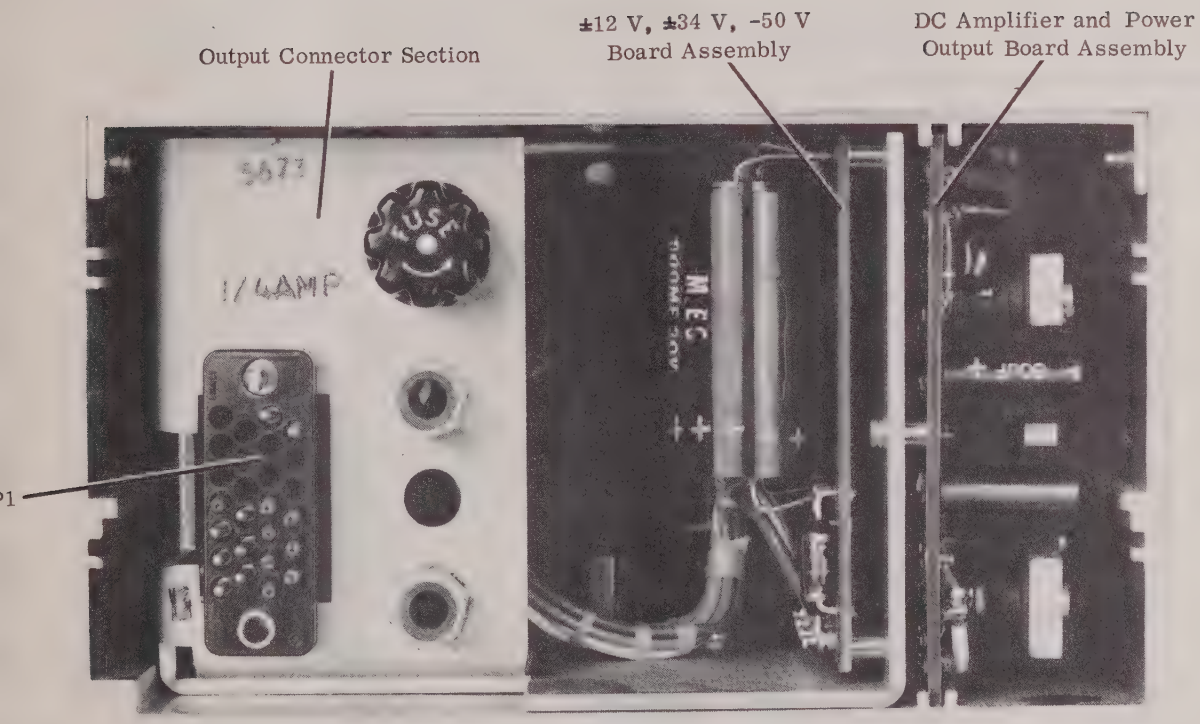


Figure 5-9. Rear View

Table 5-4. Recommended Spare Parts List, Model GFD-13

Item No.	Part Number	Description	Qty. per 10 - 12 Units
1	F1	Fuse, 1/4 amp, 125U, SB, Little Fuse	5
2	S1	Switch, 1182DL56C, Pendar	2
3	GA-013334	Power Supply Bd. Ass'y., DCS	1
4	CA-013452	Master Board Ass'y., DCS	1
5	SW200	Switch, 8002-4, Grayhill	2
6	DA-013506	Limiter and Input Meter Board Ass'y., DCS	1
7	R600	Potentiometer, Output, 500 ohm I. R. C.	1
8	GA-013547	VCO Board Assembly, DCS	1
9	TA-013497	Output Amplifier Board Ass'y. DCS	1
10	BA-013467	Lower Chopper Board Ass'y., DCS	1
11	BA-013468	Upper Chopper Board Ass'y., DCS	1
12	BD-012320	Output Meter, International	1

SECTION VI

DRAWINGS

6-1. GENERAL. The drawings listed in this section are furnished to supplement the information given in the text.

DO-013373	Outline Drawing, GFD-13
EW-013819	*Schematic Drawing, GFD-13
TW-013291	Schematic Drawing, Power Supply
BA-013332	Output Connector Ass'y., P.S. (2600)
GA-013334	P.S. Board Ass'y. (2800)
BA-013333	±18 V P.S. Board Ass'y. (2900)
TA-013497	Output Amplifier Board Ass'y. (1600)
BA-013468	Chopper Board Ass'y., Upper (1700)
BA-013467	Chopper Board Ass'y., Lower (1700)
CA-013452	Master Board Ass'y.
DA-013506	Limiter & Input Meter (200)
GA-013547	VCO Board Ass'y.
GW-014010	Schematic Reference Tuning Unit
DO-013508	Outline Drawing, GMH-13

*For Loop Filter (3400, 3500), Band Pass Filter (3100) and Low Pass Filter (4600) Schematics see Drawing EW-013819.

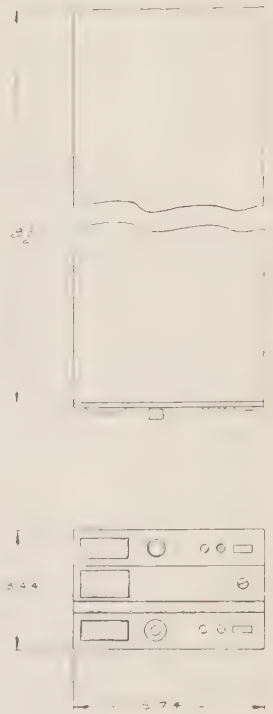
CW-018333	Schematic, Low-Pass Amplifier
AA-018203	Assembly, Low-Pass Amplifier

REVISIONS					
SYM	DESCRIPTION	DATE	BY	CHK	APP
B	ADDED ALT FUNCTIONS FOR DEMODULATORS	2/11/65	WS		

REFERENCE DEMODULATOR

P1 PLUG	
PIN NO	PIN CONNECTIONS
A	OUTPUT TAPE SPEED COMP SIGNAL
B	SUB-CARRIER MONITOR
C	OUTPUT GROUND
D	INPUT TAPE SPEED COMP SIGNAL
E	AUTO-CAL
F	INPUT MULTIPLEX
H	FEEDBACK #1
J	W&F INPUT
K	AUTO-CAL
L	CURRENT OUT (+)
M	FEEDBACK #2
N	OUTPUT, DELAYED MULTIPLEX
P	FEEDBACK
R	CURRENT OUT (-)
S	
T	
U	
V	
W	NO CONNECTION
X	
Y	
Z	
AA	
BB	AC LINE
CC	NO CONNECTION
DD	AC LINE

S1 SOCKET	
PIN NO	PIN CONNECTIONS
A	OUTPUT TAPE SPEED COMP SIGNAL
B	
C	OUTPUT GROUND
D	INPUT TAPE SPEED COMP SIGNAL
E	
F	INPUT MULTIPLEX
H	JUMPER TO M&P
J	W&F INPUT SHORTED BNC ON GMN-13
K	
L	JUMPER TO R
M	JUMPER TO M&P
N	OUTPUT, DELAYED MULTIPLEX
P	JUMPER TO M&P
R	JUMPER TO L
S	
T	
U	
V	
W	
X	
Y	
Z	
AA	
BB	115 VAC INPUT
CC	
DD	115 VAC INPUT



INPUT CONNECTOR
BURNDY MS-2GP-1

DATA DEMODULATOR

P1 PLUG	
PIN NO	PIN CONNECTIONS
A	OUTPUT
B	SUBCARRIER MONITOR
C	OUTPUT GROUND
D	SUBCARRIER INPUT
E	AUTO-CAL
F	V C O OUTPUT
H	FEEDBACK #1
J	W&F INPUT
K	AUTO-CAL
L	CURRENT OUT (+)
M	FEEDBACK #2
N	EXT ZERO
P	FEEDBACK
R	CURRENT OUT (-)
S	
T	
U	
V	
W	
X	NO CONNECTION
Y	
Z	
AA	
BB	AC LINE
CC	NO CONNECTION
DD	AC LINE

S1 SOCKET	
PIN NO	PIN CONNECTIONS
A	OUTPUT
B	
C	OUTPUT GROUND
D	SUBCARRIER INPUT
E	
F	V C O OUTPUT
H	JUMPER TO M&P
J	W&F INPUT *
K	
L	JUMPER TO R
M	JUMPER TO M&P
N	EXT. ZERO OFFSET SHORTED BNC ON GMN-13
P	JUMPER TO M&P
R	JUMPER TO L
S	
T	
U	
V	
W	
X	
Y	
Z	
AA	
BB	115 VAC INPUT
CC	
DD	115 VAC INPUT

DO-013373 B

NOTE:
1. * WHEN W&F IS NOT USED USE SHORTED BNC IN GMN-13.
2. PLUG P1 & SOCKET S1 IN GMN-13 IS WIRED IN THE SAME MANNER FOR REFERENCE DEMODULATOR OR DATA DEMODULATOR APPLICATION. SEE GMN-13 OUTLINE DWG. DO-013508 FOR EXTERNAL CONNECTIONS FOR USE AS DATA OR REF DEMODULATOR.

REF	DESCRIPTION	QTY

SYMBOL	ITEM	DWG NO	DESCRIPTION	QTY

DATA-CONTROL SYSTEMS, INC.

TITLE: OUTLINE, MODEL GFD-13 FM DEMODULATOR

TOLERANCE: DECIMAL 2 PLACE ± .010; DECIMAL 3 PLACE ± .005; FRAC 2 PLACE ± 1/64; 3 PLACE ± 1/128; PLATED SURFACE ANG; FRACTIONAL HOLES ± 1/64; BURR CREAM ALL SHARP; CHROMIUM NOT ABOVE; SURFACE ROUGHNESS NOT ABOVE

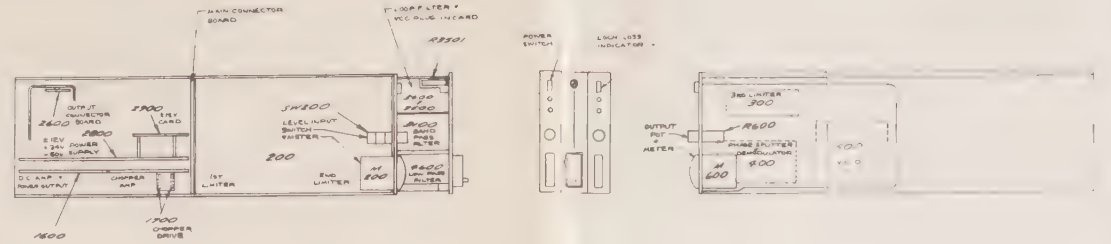
SCALE 1/2 | DATE: DO NOT SCALE DRAWING

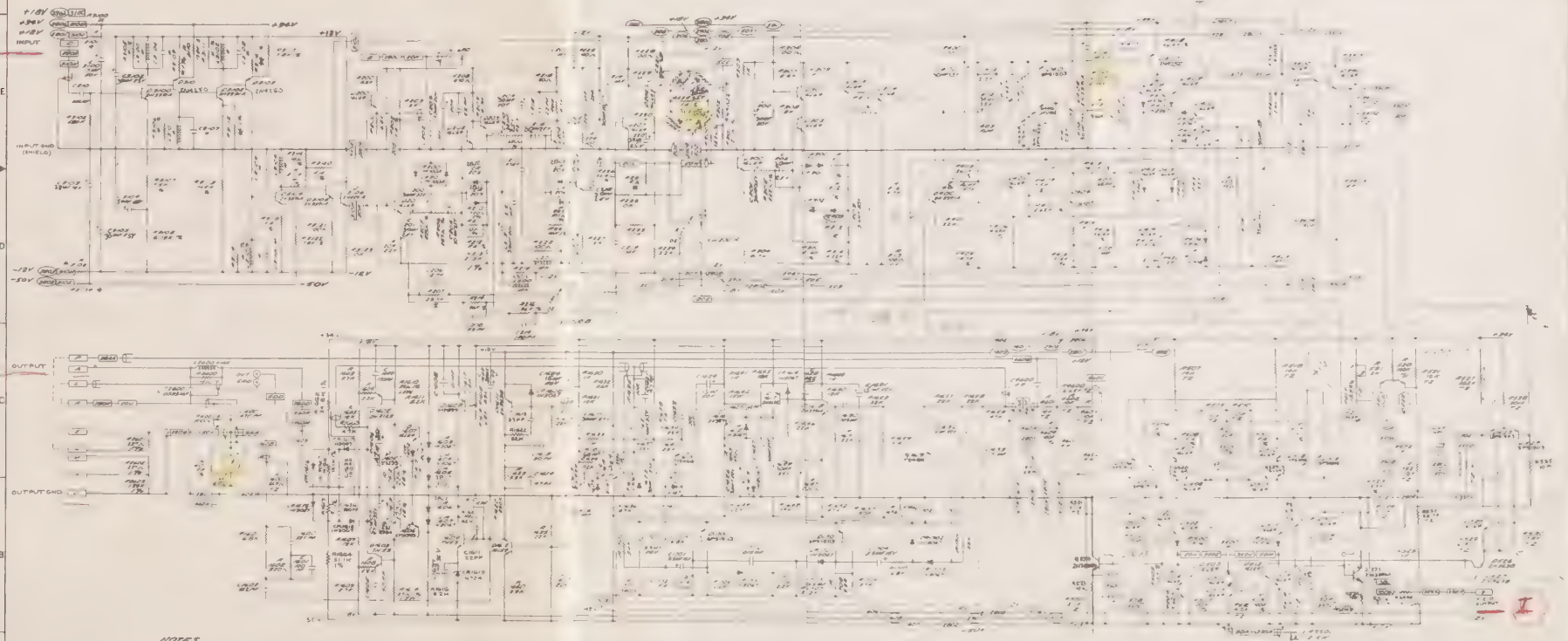
DRN. WS 2-11-65 | MAT'L

CHKD. [illegible] | FINISH

ENG. [illegible] 6/3/65 | MODEL GFD-13 | DO-013373 | REV B

NEXT ASSY





NOTES

1. * VALUE DEPENDENT ON CHANNEL FREQUENCY / DEVIATION
2. ** VALUE DEPENDENT ON LOW PASS FILTER CUTOFF CHARACTERISTICS
3. A.R. FACTORY ADJUST
4. ◯ AMP CONNECTIONS
5. □ BURNDY PIN CONNECTIONS
6. G.E. 2N3955A IS DIRECTLY INTERCHANGABLE WITH G.E. 16LG4 & G.E. 2N3955A
7. TEXAS INST. 2N3702 IS DIRECTLY INTERCHANGABLE WITH T.I. 503
8. TRANS. Q538 (T-679) ARE FACTORY ADJUST. FOR TEMP. COMPENSATION AND MAY BE REMOVED AND REPLACED WITH A JUMPER

DATA-CONTROL SYSTEMS, INC.
DANBURY, CONN

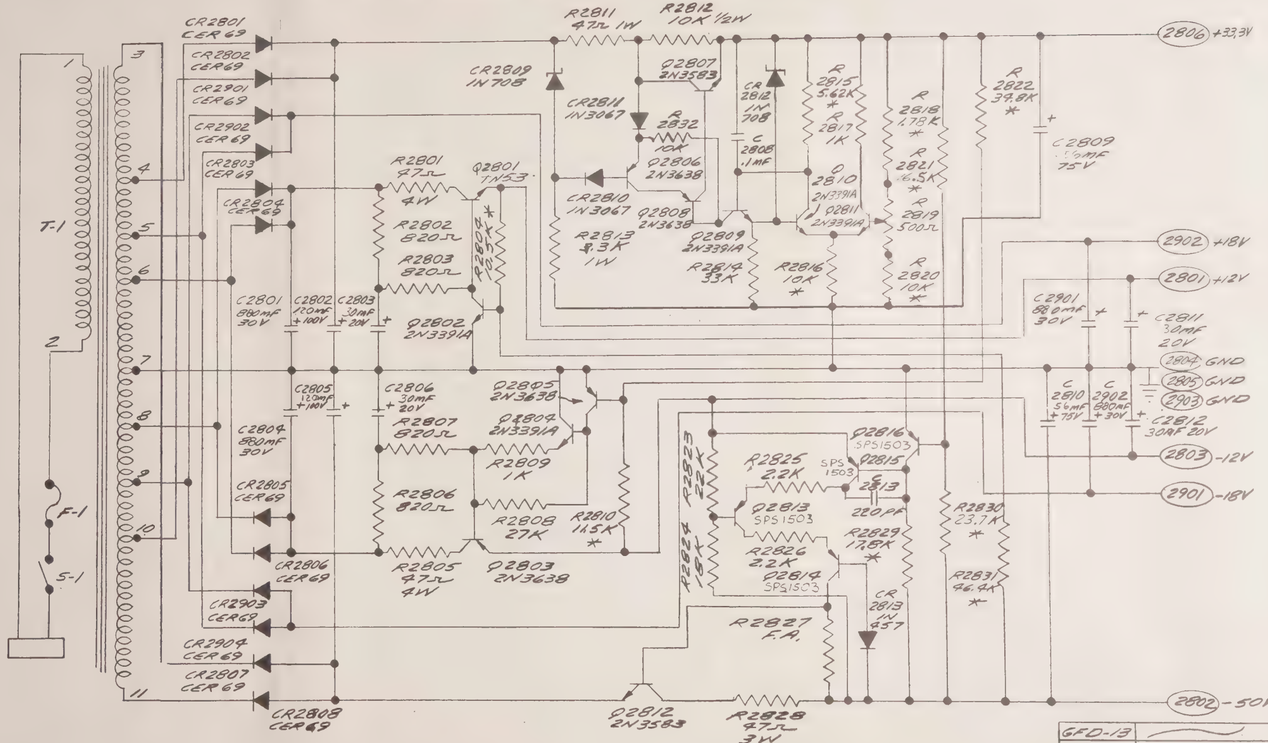
SCHEMATIC - GFD-13 DEMODULATOR

E EW-013819

REV.	DESCRIPTION	DATE	DWN.	CHK.	APP.
B	REVISED (E&E)	11/2/65	PJH		
C	-50V WAS +50V (R&E) CHANGE	5/6/65	PJH		
D	CA-2265-CHG'D. R2802 & R2830	9/15/66	PJH		
E	CA-2265-CHG'D. R2811 & R2830 VALUES	10/11/66	PJH		
F	CA-3076-CHG'D. R2814 & R2816 VALUES	5/19/67	PJH		
G	CA-3323-1-CHG'D TRANS. PART'S QTY'S	5/15/68	PJH		
H	CA-3425-CHG'D. CAP. VALUES	9/27/68	P.I.		
J	CA-3592-1 CHG'D RES. VALUES	2/21/69	PJH		

REF	DESCRIPTION	QTY

ITEM	SYMBOL	DWG. NO.	DESCRIPTION	QTY.
		TW-013291	J	



NOTES:
1. 2900 SERIES COMPONENTS ARE LOCATED ON +18V BOARD ASSEMBLY.
2. REF. ASSY' DRAWINGS FOR POWER SUPPLY ARE E
3. ⬭ ELCO PIN CONNECTIONS
4. ▭ CONNECTOR
5. RESISTORS MARKED * ARE 1%

GFD-13		REF
FIRST PRODUCT	NEXT ASSEMBLY	QTY. ASSY

DATA CONTROL SYSTEMS, INC.

TITLE: SCHEMATIC - POWER SUPPLY

TOLERANCES: UNLESS OTHERWISE SPECIFIED
DECIMAL - 3 PLACE ± .005
DECIMAL - 2 PLACE ± .010
FRAC. ± 1/64 ANG. ± 0°30'
FLATNESS WITHIN — IN.
FRACTIONAL HOLES 0 + 1/64
NOTE: BREAK ALL SHARP CORNERS .005" - .015"
SURFACE ROUGHNESS NOT TO EXCEED

DO NOT SCALE DRAWING

		DATE
DWN.	PJH	10/65
CHKD	BAH	5/14/68
ENG	BAH	6/24/68
APP.	PJH	11/4/68
MAT'L		
FINISH		
SCALE		

TW-013291 REV J

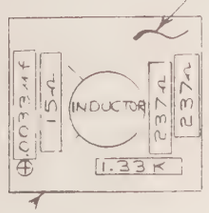
SHEET

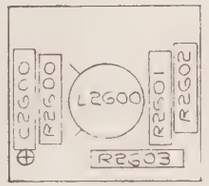
REV.	DESCRIPTION	DATE	DWN.	CHK.	APP.
C	CA 3410. REDRAWN TO LATEST DWG. STDS.	8/15/66	DR		
D	CA 3471 - ADDED CAP. C 2601	10/21/66	"		
E	CA 3471-1 - DELETED C 2601	10/24/66	"		
F	CA-508. ADD NOTE #3	5-23-67	GCD		

B — REV.

STAMP D.C.S. PART NO. IN 1/8 HIGH CONTRASTING CHARACTERS APPROX. AS SHOWN

ITEM	SYMBOL	DWG. NO.	DESCRIPTION	QTY./ASSY
1		BF-013305	BD FAB, OUTPUT CONN.	1
	R2600		RES, AB EB 1/2W, 5%, 15Ω	1
	R2601		WLCGO-T2, 1/4W, 1%, 237Ω	1
	R2602		237Ω	1
	R2603		1.33K	1
	C2600		CAP AEROVOX, 1848, 200V, .0033μf	1
			SLEEVING #22	A/R
#	L2600	BA-014062	INDUCTOR	1





NOTES:
1) # - SEE ASS'Y. DWG. FOR COMPONENT PARTS.
2) ⊕ - DENOTES OUTSIDE FOIL END.
3) SLEEVE (#22) LEADS ON R2603

REF.	DESCRIPTION	QTY

PRODUCT	NEXT ASSEMBLY	QTY./ASSY.
GFD-13	DA-013970	

DATA CONTROL SYSTEMS, INC.

TITLE: BD ASS'Y., OUTPUT CONN. POWER SUPPLY

TOLERANCES: UNLESS OTHERWISE SPECIFIED
DECIMAL - 3 PLACE ± .005
DECIMAL - 2 PLACE ± .010
FRAC. ± 1/64 ANG. ± 0°30'
FLATNESS WITHIN ~ /IN.
FRACTIONAL HOLES -0, + 1/64
NOTE- BREAK ALL SHARP CORNERS .005"-.015"
SURFACE ROUGHNESS NOT TO EXCEED ~

		DATE
DWN.	DR	8/15/66
CHKD		8/17/66
ENG.		8/11/66
APP.		8/17/66
SCALE	NONE	

DO NOT SCALE DRAWING
MAT'L —"—
FINISH —"—

BA 013332 REV. F

SHEET

REV.	DESCRIPTION	DATE	DWN	CHK	APP
D	CA 3410. REDRAWN TO LATEST STDS. DWG. WAS 'G' SIZE (15H.)	7/19/66	DR		
E	CA-3455 - CHG. MFG. PART NO. SPRAGUE	9/28/66	PE		
F	CA-3592 - CHGD RES. VALUES	2/21/67	[illegible]		
G	CA-4857 - CHG'D R2819	12/11/67	JEH	[illegible]	MR

NOTES:
1) ITEM # 3, R2828, Q2807, AND Q2812 TO BE PREASSEMBLED PER DWG. BA-013537, THEN MOUNTED TO ITEM # 1.
2) ITEM # 4, R2801, AND R2805 TO BE PREASSEMBLED, THEN MOUNTED TO ITEM # 1.
3) * - LATEST REVISION.
4) ** - SCREW LENGTHS TO BE DETERMINED IN ACCORDANCE WITH DCS WORKMANSHIP MANUAL AS-832011.
5) ITEM 5 TO MOUNT UNDER TRANS. Q2802, Q2804, Q2809, Q2810, Q2811, Q2813, Q2814, Q2815, AND Q2816.
6) ITEM 6 TO MOUNT UNDER TRANS. Q2801.
7) ITEM 7 TO MOUNT UNDER TRANS. Q2803, Q2805, Q2806, AND Q2808.

REF	DESCRIPTION	QTY

				REV.
Q2801		TRANS, SPRAGUE, TN53		1
Q2802		G.E.,	2N3391A	1
Q2803		FAIRCHILD,	2N3638	1
Q2804		G.E.,	2N3391A	1
Q2805		FAIRCHILD,	2N3638	1
Q2806		↓	2N3638	1
Q2807	(SEE NOTE #1)	RCA,	2N3583	1
Q2808		FAIRCHILD,	2N3638	1
Q2809		G.E.,	2N3391A	1
Q2810		↓	2N3391A	1
Q2811		↓	2N3391A	1
Q2812	(SEE NOTE #1)	RCA,	2N3583	1
Q2813		MOTOROLA,	SPS1503	1
Q2814		↓	SPS1503	1
Q2815		↓	SPS1503	1
Q2816		↓	SPS1503	1

	PART NO.	T	REV.
R2825		RES, AB, CB, 1/4W, 10%, 2.2K	1
R2826		2.2K	1
R2827		↓ (NOM.) FA (105K)	1
R2828	(SEE NOTE #1)	AB, GM, 3W, 47Ω	1
R2829		ELEC., MFSCD, 1/8W, 1.8K	1
R2830		WLCGO-T2, 1/4W, 1%, 23.7K	1
R2831		↓ 46.4K	1
R2832		↓ AB, CB, 1/4W, 10%, 10K	1
CR2801		DIODE, SOLITRON, CER G9	1
CR2802		CER G9	1
CR2803		CER G9	1
CR2804		CER G9	1
CR2805		CER G9	1
CR2806		CER G9	1
CR2807		CER G9	1
CR2808		CER G9	1
CR2809		CONT. DEV., 1N708	1
CR2810		1N3067	1
CR2811		1N3067	1
CR2812		1N708	1
CR2813		1N457	1
C2801	601D887G030HJ4	CAP., SPRAGUE, 30V, 880μF	1
C2802	39D127F100GJ4	100V, 120μF	1
C2803		GENT, 101D, DS-283, 20V, 30μF	1
C2804	601D887G030HJ4	SPRAGUE, 30V, 880μF	1
C2805	39D127F100GJ4	↓ 100V, 120μF	1
C2806		GENT, 101D DS-283, 20V, 30μF	1
C2808		BT, RMC, 100V, .1μF	1
C2809	109D566X0075T2	SPRAGUE, 75V, 56μF	1
C2810	109D566X0075T2	↓ 75V, 56μF	1
C2811		GENT, 101D, DS-283, 20V, 30μF	1
C2812		↓ ↓ 20V, 30μF	1
C2813		↓ DURMICA, DM-15, 220μμF	1

SEE SHEET 2 OF 2 FOR ASS'Y. DWG.

GFD-13	DA-013970	1
FIRST PRODUCT	NEXT ASSEMBLY	QTY. USED

ITEM	SYMBOL	DWG. NO	DESCRIPTION	QTY. USED
1		CF-013295	BD FAB, POWER SUPPLY	1
2		BA-013333	BD ASS'Y, 18V P.S.	1
3		BA-013537	BRKT. ASS'Y., POWER TRANS	1
4		BF-013386	BRKT FAB., RES. MTG.	1
5			PAD, TRANS., THERMALLOY, 7717-2N WHITE	A/R
6			PAD, TRANS., ROSS #100GB	A/R
7			PAD, TRANS., #294-250 MAYAGUEZ MILLS	A/R
8	**	AS-826028 #40	SCREW, #4-40 PHMS	A/R
9	**	AS-826028 #26	SCREW, #2-56 PHMS	A/R
10			JUMPER, #22 BUSS WIRE	A/R
11		AS-826018 #04	WASHER, SPLITLOCK	A/R
12		AS-826017 #04	↓ FLAT	A/R
13		AS-826017 #02	↓ FLAT	A/R
14		AS-826018 #02	↓ SPLITLOCK	A/R
15			HEX NUT, #4-40 CAD. PL. CRS	1
	R2801	(SEE NOTE #2)	RES., AB, HM, 4W, 47Ω	1
	R2802		AB, CB, 1/4W, 10%, 820Ω	1
	R2803		↓ 820Ω	1
	R2804		WLCGO-T2, 1/4W, 1%, 10.5K	1
	R2805	(SEE NOTE #2)	AB, HM, 4W, 47Ω	1
	R2806		AB, CB, 1/4W, 10%, 820Ω	1
	R2807		↓ 820Ω	1
	R2808		↓ 27K	1
	R2809		↓ 1K	1
	R2810		WLCGO-T2, 1/4W, 1%, 11.5K	1
	R2811		AB, GB, 1W, 47Ω	1
	R2812		AB, EB, 1/2W, 10%, 10K	1
	R2813		AB, GB, 1W, 3.3K	1
	R2814		AB, CB, 1/4W, 10%, 33K	1
	R2815		WLCGO-T2, 1/4W, 1%, 5.62K	1
	R2816		↓ 10.0K	1
	R2817		AB CB 1/4W, 10%, 1K	1
	R2818		WLCGO-T2 1/4W, 1% 1.78K	1
	R2819		AMPHENOL, [illegible] 500Ω	1
	R2820		WLCGO-T2 1/4W, 1% 10.0K	1
	R2821		↓ 16.5K	1
	R2822		↓ 34.8K	1
	R2823		AB, CB 1/4W, 10%, 2.2K	1
	R2824		↓ 8K	1

DCS DATA CONTROL SYSTEMS, INC.

TITLE: BD ASS'Y, POWER SUPPLY

TOLERANCES UNLESS OTHERWISE SPECIFIED
DECIMAL - 3 PLACE ± .005
DECIMAL - 2 PLACE ± .010
FRAC. ± 1/64 ANG. ± 0°30'
FLATNESS WITHIN .001 IN
FRACTIONAL HOLES Ø ± 1/64
NOTE: BREAK ALL SHARP CORNERS .005 - .015
SURFACE ROUGHNESS NOT TO EXCEED

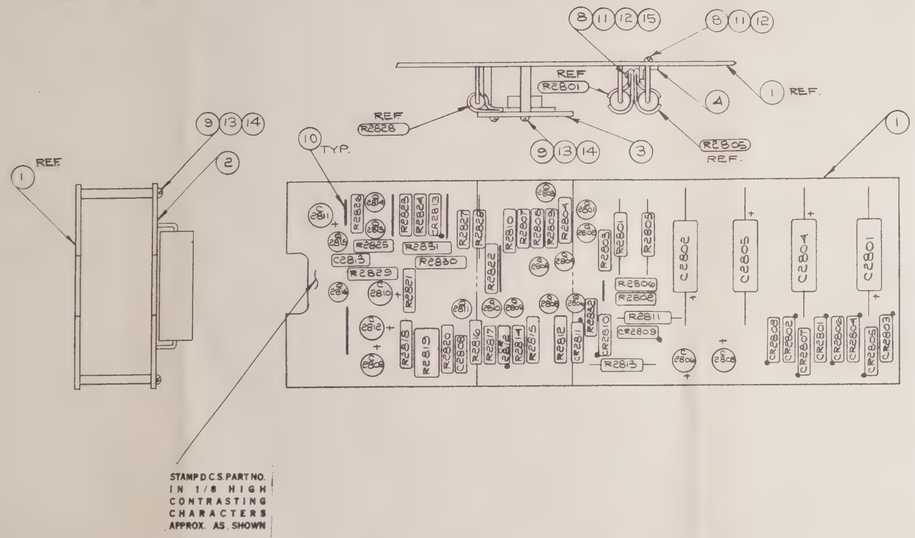
DWN: [illegible] DATE: [illegible]
CHKD: [illegible]
ENGR: [illegible]
APP: [illegible]
SCALE: NONE

DO NOT SCALE DRAWING
MATL: -4
FINISH: -4

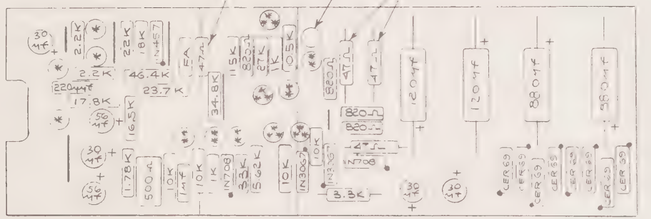
TA-013384 REV. G

SHEET 1 OF 2

REV	DESCRIPTION	DATE	DWN	CHK	APP
D	CA 3410. REDRAWN TO LATEST STDS. DWG. WAS 'G' SIZE. (SH.1)	7/8/66	DR		
E	CA-3455: CHG'D. CAP. VALUES	9/28/66	DR		
F	CA-3593 CHG'D RES. VALUES	11/2/67			
G	CA 4857 - CHG'D R2819	12/7/67	JGH		



REF	DESCRIPTION	QTY



*- SPS 1603 AND ITEM 5
**- 2N3991A AND ITEM 6
***- 3N138 AND ITEM 7
• - DENOTES CATHODE END

SEE SHEET 1 OF 2 FOR PARTS LIST & NOTES.

REV	ITEM	SYMBOL	DWG NO	DESCRIPTION	QTY / ASSY
T					

GFD-13	DA-013970	1
FIRST PRODUCT	NEXT ASSEMBLY	QTY / ASSY

DATA CONTROL SYSTEMS, INC.

TITLE: BD ASS'Y., POWER SUPPLY.

TOLERANCES UNLESS OTHERWISE SPECIFIED
DECIMAL - 3 PLACE ± .005
DECIMAL - 2 PLACE ± .010
FRAC. ± 1/64 ANG. ± 0°30'
FLATNESS WITHIN — /IN
FRACTIONAL HOLES -0, + 1/64
NOTE- BREAK ALL SHARP CORNERS .005", .015" SURFACE ROUGHNESS NOT TO EXCEED ~

		DATE
DWN	DR	7/8/66
CHKD		
ENG		11/2/66
APP		12/7/66
SCALE	NONE	

DO NOT SCALE DRAWING
MAT'L —
FINISH —

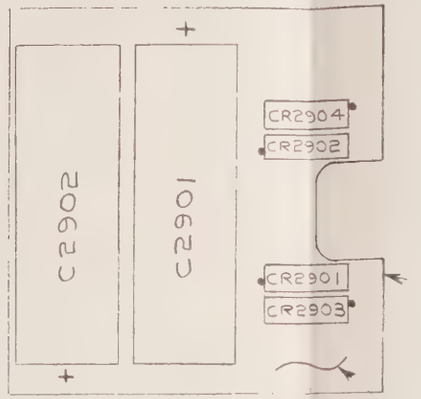
TA-013334 REV. G

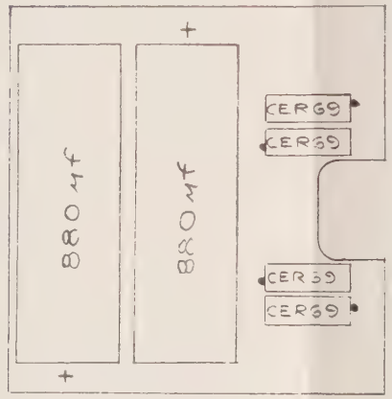
SHEET 2 OF 2

REV	DESCRIPTION	DATE	DWN.	CHK.	APP.
B	CA 3410 REDRAWN TO LATEST DWG. STDS.	8/12/66	DR		
C	CA 3410-1 MFG. DIED. SHP. TO SPRAGUE.	9/30/66	WI		

B — REV

ITEM	SYMBOL	DWG. NO.	DESCRIPTION	QTY/ASSY
1		BF-013300	BD FAB, 18V. P.S.	1
	C2901		CAP. SPRAGUE 601D6B7G030HJ9, 30V, 680MF	1
	C2902		30V, 680MF	1
	CR2901		DIODE SOLITRON, CERG9	1
	CR2902		CERG9	1
	CR2903		CERG9	1
	CR2904		CERG9	1





1 - STAMP D.C.S. PART NO. IN 1/8 HIGH CONTRASTING CHARACTERS APPROX. AS SHOWN

● - DENOTES CATHODE END

REF.	DESCRIPTION	QTY

PRODUCT	NEXT ASSEMBLY	QTY./ASSY.
GFD-13	TA-013334	1

DATA CONTROL SYSTEMS, INC.

TOLERANCES: UNLESS OTHERWISE SPECIFIED
DECIMAL - 3 PLACE ± .005
DECIMAL - 2 PLACE ± .010
FRAC. ± 1/64 ANG. ± 0°30'
FLATNESS WITHIN ~ /IN.
FRACTIONAL HOLES -0, + 1/64
NOTE- BREAK ALL SHARP CORNERS .005' - .015' SURFACE ROUGHNESS NOT TO EXCEED ~

TITLE: BD ASSY. 18V. POWER SUPPLY

		DATE
DWN	DR	8-2-66
CHKD		
ENG.		
APP.		

SCALE NONE

DO NOT SCALE DRAWING

MAT'L —

FINISH —

BA-013333 — REV. C

SHEET

ITEM	SYMBOL	DESCRIPTION	QTY. REQ'D
	CR 1606	DIODE G.E. 28J8	1
	CR 1607	CONT. DEVICES, IN3067	1
	CR 1608	" " "	1
	CR 1609	" " "	1
	CR 1610	" " "	1
	CR 1611	" " "	1
	CR 1612	" " "	1
	CR 1613	" " "	1
	CR 1614	" " "	1
	CR 1615	" " "	1
	CR 1616	" " "	1
	CR 1617	" " "	1
	CR 1618	" " "	1
	CR 1619	" " "	1
	C1600	CAP. DURMICA, DM-10, 221 mmf.	1
	C1601	" " 100 mmf.	1
	C1602	DM-15, 562 mmf.	1
	C1604	DM-10, 150 mmf.	1
	C1605	" 150 mmf.	1
	C1606	SPRAGUE, 150D474 X0020A2, 35V ±20% .47 mf	1
	C1607	" .47 mf	1
	C1608	BT, RMC, 100V, .01 mf	1
	C1609	GENT. BD-014132, 25V 30 mf	1
	C1610	DURMICA, DM-10, 15 mmf.	1
	C1611	22 mmf.	1
	C1612	33 mmf.	1
	C1613	30 mmf.	1
	C1614	47 mmf.	1
	C1616	BT, RMC, 100V. .01 mf	1
	C1617	GENT. BD-014132, 25V. 30 mf	1
	C1618	DURMICA, DM-10, 68 mmf	1
	C1619	47 mmf	1
	C1620	GENT. 1010, 25 V. 10 mf	1

ITEM	SYMBOL	DESCRIPTION	QTY. REQ'D
	R1636	RES. AB, CB, 1/4 W. 10%, 47 K	1
	R1637	33 K	1
	R1638	(MFC) FA 820 Ω	1
	R1639	33 K	1
	R1640	33 K	1
	R1641	1K	1
	R1642	15K	1
	R1643	47 Ω	1
	R1644	22 K	1
	R1645	18 K	1
	R1646	22 K	1
	R1647	220 Ω	1
	R1648	39 K	1
	R1649	1 K	1
	R1650	12 K	1
	R1651	22 K	1
	R1652	4.7 K	1
	R1653	22 K	1
	R1654	(MFC) FA 6.8 K	1
	R1655	150 K	1
	R1656	470 Ω	1
	R1657	22 K	1
	R1658	22 K	1
	R1659	47 K	1
	R1660	3.9 K	1
	R1661	ELEC. MFSC-D, 1/4 W. 1% 12.10 K	1
	R1662	34.80 K	1
	R1663	12.10 K	1
	R1664	51.10 K	1
	R1665	AB, CB, 1/4 W. 1% 4.7 K	1
	1602	DIODE, CONT. DEVICES, IN3067	1
	CR 1603	" " "	1
	CR 1604	" " "	1
	CR 1605	G.E. 28J2	1

ITEM	SYMBOL	DESCRIPTION	QTY. REQ'D
	R1600	RES. WLC60-T2, 1/4 W. 1% 61.9 Ω	1
	R1601	AB, CB, 1/4 W. 10% 6.8 K	1
	R1602	820 Ω	1
	R1603	2.7 K	1
	R1604	2.2 K	1
	R1605	12 K	1
	R1607	12 K	1
	R1608	2.2 K	1
	R1609	2.7 K	1
	R1610	MEPCO 1.5 W, 1% 27 Ω	1
	R1611	AB, CB, 1/4 W. 10% 8.2 K	1
	R1612	AB, EB, 1/2 W. 10% 22 Ω	1
	R1613	AB, EB, 1/2 W. 10% 22 Ω	1
	R1614	MEPCO 1.5 W 1% 27 Ω	1
	R1615	AB, CB, 1/4 W. 10% 1K	1
	R1616	82 K	1
	R1617	1.2 K	1
	R1618	3.3 K	1
	R1619	6.8 K	1
	R1620	220 K	1
	R1621	82 K	1
	R1622	82 K	1
	R1623	3.3 K	1
	R1625	22 K	1
	R1627	22 K	1
	R1628	2.2 K	1
	R1629	22 K	1
	R1630	1 K	1
	R1631	12 K	1
	R1632	5.6 K	1
	R1633	1M	1
	R1634	82 K	1
	R1635	10 K	1

ITEM	SYMBOL	PART NO	DESCRIPTION	QTY. REQ'D
1		CF-013393	BD. FAB. OUTPUT AMP	1
2		BD-013403	COVER CHOPPER DRIVE	1
3		BA 013437	BD ASSY CHOPPER (LOWER)	1
4		BA-013468	BD ASSY CHOPPER (UPPER)	1
5		BD-013326	HEATSINK	1
6			HEAT DIS, IERC, TAB 223, BOT 223	5
7			HEAT DIS, IERC, TAB 223, BOT 223	3
8		AS-826028#26	SCREW, #2-56 PHMS (# #)	A/R
9		AS-826028#40	SCREW, #4 40 PHMS (# #)	A/R
10			JUMPER, #22 BUSS WIRE	A/R
11			PAD, TRANS, ROSS #10042	A/R
12			PAD, TRANS, ROSS #10068	A/R
13			PAD, TRANS, MAY ADDC #133-236	A/R
14			TAB SHRINK TUBE #N-187-2	2
15			THERMOSET SLEEVE (CLEAR)	A/R
16		(SEE NOTE #1)	COAX. CONTACT BURNDY FEMALE	1
17		(SEE NOTE #2)	COAX. CONTACT BURNDY MALE	1
18			LUG, MALCO #755	1
19		AS-826JW#02	WASHER FLAT	A/R
20		AS-826JW#02	LOCK WASHER	A/R
21			PAD, TRANS THERMALOY #TT-1-2M, WHITE	
22				
	C1621		CAP DURMICA, DM-10, 47 mmf	1
	C1622		GENT. BD-014132, 25V. 30 mf	1
	C1623		BT, RMC, 100V .005 mf	1
	C1624		GENT. BD-014133, 50V 15 mf	1
	C1625		DURMICA, DM-10, 62 mmf	1
	C1626		SPRAGUE, 150D 476 X0020A2, 35V ±20% 30 mf	1
	C1627		GENT. BD-014132, 25V 3 mf	1
	C1628		BT, RMC, 100V .025 mf	1
	C1629		GENT BD-014132, 25V 30 mf	1
	C1630		BT, RMC, 100V .005 mf	1
	C1631		GENT BD 014133, 50V, 15 mf	1
	C1632		SEMICOR, 50V 20% .15 mf	1
	C1633		BT, RMC, 100V .01 mf	1
	C1634		GENT BD-014133, 50V 15 mf	1

REV	DESCRIPTION	DATE	DWN	CHK	APP
U	ME, REDRAWN WITHOUT CHG.	5/3/67	GCD	MR	MR
V	CA 5086, C1620 & 1608	6-7-67	GCD	MR	MR

ITEM	SYMBOL	DESCRIPTION	QTY. REQ'D
	C1635	CAP DURMICA, DM-10, 100 mmf	1
	C1636	" " 100 mf	1
	C1637	SPRAGUE, 150D 337 X0050B2 50V ±20% 3 mf	1
	Q1602	TRANS MOTOROLA, 2N3133	1
	Q1603	SPRAGUE, TN53	1
	Q1604	MOTOROLA, 2N2904	1
	Q1605	SPRAGUE, TN53	1
	Q1606	MOTOROLA, SPS9013	1
	Q1607*	GE 2N3565A	1
	Q1608	FAIRCHILD, 2N4258	1
	Q1609	SPRAGUE, TN53	1
	Q1611	FAIRCHILD, 2N3858	1
	Q1612	GE 2N3565A	1
	Q1613	2N3391A	1
	Q1614	2N3391A	1
	Q1615	SPRAGUE, T2456	1
	Q1616	GE 2N3711	1
	Q1617	FAIRCHILD 2N3638	1
	Q1618	GE 2N 3391A	1
	Q1619	SPRAGUE, T2456	1

NOTES:
1) ITEM #17 CONSISTS OF
1 RCDX-607
1 MP1026L
1 RSCIB4559-1
1 YOC-C174
2) ITEM #18 CONSISTS OF
1 HMA-60-1
1 RFL2661
1 RAIA3455-1
1 YOC-C174

GFD-13	DA-013396	1	
PRODUCT	NEXT ASSEMBLY	QTY. / ASSY.	

DATA CONTROL SYSTEMS, INC.

TITLE: BD. ASSY, OUTPUT AMP

TOLERANCES UNLESS OTHERWISE SPECIFIED
DECIMAL: 3 PLACE ± .005
DECIMAL: 2 PLACE ± .010
FRAC. ± 1/64 ANG. ± 0°30'
FLATNESS WITHIN .001 IN
FRACTIONAL HOLES Ø- + 1/64
NOTE: BREAK ALL SHARP CORNERS .005"-.015" SURFACE ROUGHNESS NOT TO EXCEED ✓

	NAME	DATE
DWN	G. DYER	5/3/67
CHKD	MR	5/3/67
ENG.		
APP.	MR	5/16/67
SCALE	NONE	

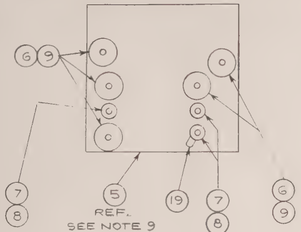
DO NOT SCALE DRAWING
MAT'L —
FINISH —

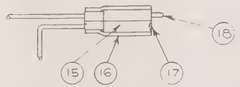
T A - 0 1 3 4 9 7 REV. V

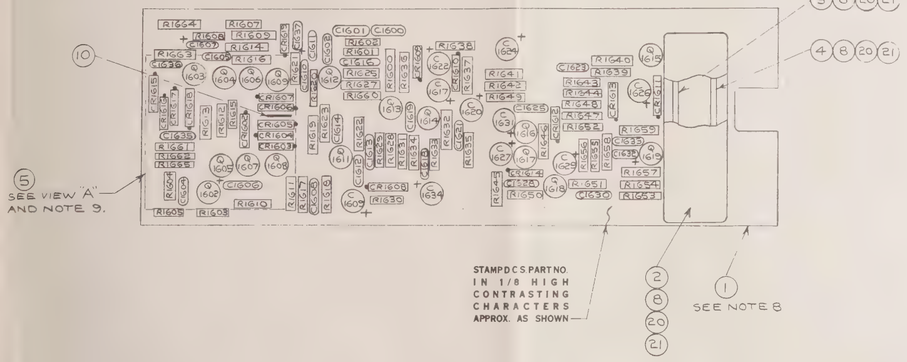
SHEET 1 OF 2

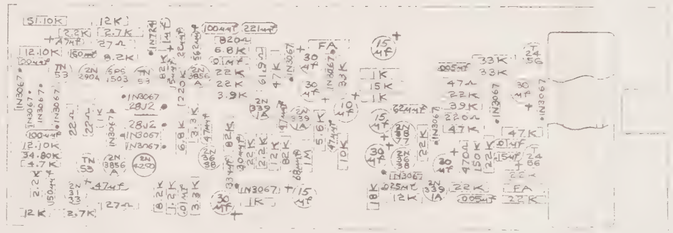
REV.	DESCRIPTION	DATE	DWN.	CHK	APP
K	CA 3410. REDRAWN TO LATEST STDS., SHEET 2 ONLY. TRANSFERED NOTES TO SHEET 1.	8/2/66	DR		
L	CA-3455 - CHG'D CAP VALUES	8/23/66	PE		
M	CA3550-1 CHG'D CR1605, 1606 MFG.	1/27/67	PE		
N	CA-3573 CHG'D CAP C1618 & C1621	3/9/67			
P	CA-3598H CHG'D DIODE VALUES	4/22/67			
R	CA-3650-3 CHG'D DIODE VALUES	6/22/67			
S	CA-4319 CHG'D TRANS VALUE	A-8-68			
T	CA-4380 CHG'D R1612 & R1613	12/5/68	JEH		
U	ME REDRAWN WITHOUT CHG.	5/13/69	GCD		
V	CA-5086, CHG'D Q1608	6-2-69	GCD		

REF	DESCRIPTION	QTY






10
5
SEE VIEW 'A' AND NOTE 9.
3 8 20 21
4 8 20 21
STAMP DCS PART NO. IN 1/8 HIGH CONTRASTING CHARACTERS APPROX. AS SHOWN
2 8 20 21
1
SEE NOTE 8



* - DENOTES CATHODE END

T	REV.	ITEM	SYMBOL	DWG. NO.	DESCRIPTION	QTY/ASSY

NOTES:

3) **SCREW LENGTHS PER DCS WORKMANSHIP MANUAL AS-8392011.
4) ITEM #11 TO MOUNT UNDER TRANS. Q1608, Q1615 & Q1619.
5) ITEM #12 TO MOUNT UNDER TRANS Q1602, Q1603, Q1604, Q1605, & Q1609.
6) ITEM #13 TO MOUNT UNDER TRANS. Q1607 & Q1606.
7) ITEMS #2, #3, & #4 TO BE PREASSEMBLED, THEN MOUNTED TO ITEM #1.
8) ITEMS #6 & #7 SUPPLIED WITH SHOULDER WASHERS & MTG. SCREWS. OMIT SCREWS & SUBSTITUTE ITEMS #8 & #9. PLACE ITEM #19 BETWEEN ITEMS #5 & #7 AS SHOWN IN VIEW 'A'. PREASSEMBLE, BUT DO NOT TIGHTEN ITEMS #5, #6, #7, #8, #9 & #19. MOUNT ASSY ON TRANS. Q1602, Q1603, Q1604, Q1605, Q1606, Q1607, Q1608 & Q1609, THEN TIGHTEN SCREWS.

SEE SHEET 1 OF 2 FOR PARTS LIST & NOTES

GFD-13	DA-013976	1
FIRST PRODUCT	NEXT ASSEMBLY	QTY/ASSY

DCS DATA CONTROL SYSTEMS, INC.

TITLE: BD ASS'Y., OUTPUT AMPLIFIER

TOLERANCES: UNLESS OTHERWISE SPECIFIED
DECIMAL - 3 PLACE ± .005
DECIMAL - 2 PLACE ± .010
FRAC. ± 1/64 ANG. ± 0°30'
FLATNESS WITHIN ~/1K
FRACTIONAL HOLES Ø .4 1/64
NOTE: BREAK ALL SHARP CORNERS .005", .015" SURFACE ROUGHNESS NOT TO EXCEED ~/

		DATE
DWN	DR	8/2/66
CHK'D		8/17/66
ENG		8/18/66
APP		8/19/66
SCALE	NONE	

DO NOT SCALE DRAWING
MAT'L —
FINISH —

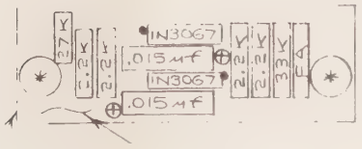
TA-013497 REV V

SHEET 2 OF 2

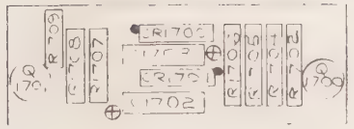
REV.	DESCRIPTION	DATE	DWN.	CHK.	APP.
C	CA3410. REDRAWN TO LATEST DWG. STDS.	8/15/66	DR		

B REV.

ITEM	SYMBOL	DWG. NO.	DESCRIPTION	QTY./ASSY
1		PF-013331	BD FAB, CHOPPER	1
2			PAD, TRANS., ROSS #10042	2
	R1702		RES., AB, CB, 1/4W, 10%, F.A.	1
	R1704		33K	1
	R1705		2.2K	1
	R1706		2.2K	1
	R1707		2.2K	1
	R1708		2.2K	1
	R1709		27K	1
	C1702		CAP., AEROVOX 184B .015 mf	1
	C1703		.015 mf	1
	CR1700		DIODE, CONT. DEV., IN3067	1
	CR1701		IN3067	1
	Q1700		TRANS. MOTOROLA SPS1503	1
	Q1701		SPS1503	1



STAMP D.C.S. PART NO. IN 1/8 HIGH CONTRASTING CHARACTERS APPROX. AS SHOWN



* - SPS1503 AND ITEM 2

• - DENOTES CATHODE END

⊕ - DENOTES OUTSIDE FOIL END

REF.	DESCRIPTION	QTY

PRODUCT	NEXT ASSEMBLY	QTY./ASSY.
GFD-13	TA-013497	1

DATA CONTROL SYSTEMS, INC.

TITLE: BD ASS'Y., CHOPPER (UPPER)

TOLERANCES: UNLESS OTHERWISE SPECIFIED
DECIMAL - 3 PLACE ± .005
DECIMAL - 2 PLACE ± .010
FRAC. ± 1/64 ANG. ± 0°30'
FLATNESS WITHIN ~ /IN.
FRACTIONAL HOLES -0, + 1/64
NOTE- BREAK ALL SHARP CORNERS .005"-.015"
SURFACE ROUGHNESS NOT TO EXCEED ~

		DATE
DWN	DR	8/15/66
CHKD		8/17/66
ENG.		8/19/66
APP.		8/19/66
SCALE	NONE	

DO NOT SCALE DRAWING
MAT'L
FINISH

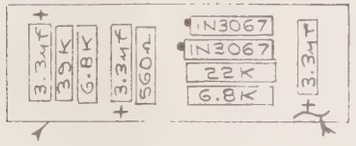
BA-013468 REV. C

SHEET

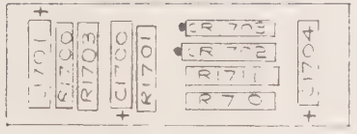
REV	DESCRIPTION	DATE	DWN.	CHK.	APP.
C	CA 3410. REDRAWN TO LATEST DWG. STDS.	8/15/66	DR		

B REV.

ITEM	SYMBOL	DWG. NO.	DESCRIPTION	QTY./ASSY
1		BF-013329	BD FAB, CHOPPER	1
	R1700		RES, AB, CB, 1/4W, 10%, 39K	1
	R1701		560Ω	1
	R1703		6.8K	1
	R1710		6.8K	1
	R1711		22K	1
	C1700		CAP, SPRAGUE, 150D, 15V, 3.3μf	1
	C1701		15V, 3.3μf	1
	C1704		15V, 3.3μf	1
	CR1702		DIODE, CONT. DEV., 1N3067	1
	CR1703		1N3067	1



(1) STAMP D.C.S. PART NO IN 1/8 HIGH CONTRASTING CHARACTERS APPROX. AS SHOWN



• - DENOTES CATHODE END.

REF.	DESCRIPTION	QTY

GFD-3	TA-0 3497	1
PRODUCT	NEXT ASSEMBLY	QTY./ASSY.

DATA CONTROL SYSTEMS, INC.

TITLE BD ASS'Y. CHOPPER (LOWER)

TOLERANCES: UNLESS OTHERWISE SPECIFIED
DECIMAL - 3 PLACE ± .005
DECIMAL - 2 PLACE ± .010
FRAC. ± 1/64 ANG. ± 0°30'
FLATNESS WITHIN — /IN.
FRACTIONAL HOLES -0. + 1/64
NOTE- BREAK ALL SHARP CORNERS .005"-.015"
SURFACE ROUGHNESS NOT TO EXCEED —

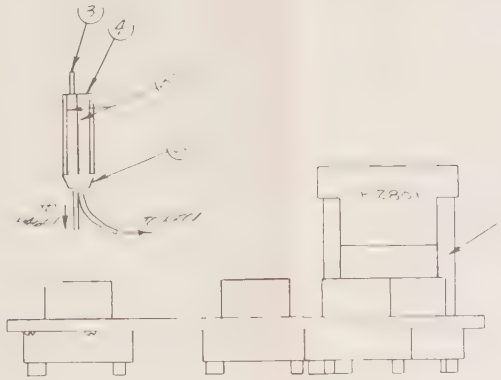
DWN. DR DATE 8/1-/66
CHKD [illegible] 8/17
ENG. [illegible]
APP. [illegible] 8/24/66
SCALE NONE

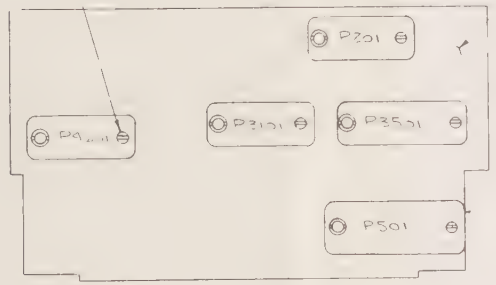
DO NOT SCALE DRAWING
MAT'L —
FINISH —

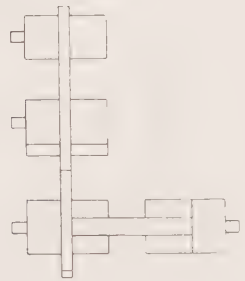
BA-013467 REV. B
SHEET

REV	DATE	DESCRIPTION	BY	CHK	APP'D
B	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C	[illegible]	CA-2957 - SAMTEC ITEM 3 & 4 ALTERNATE ITEM 4	[illegible]	[illegible]	[illegible]
D	[illegible]	CA-3036-1 REQ'D FROM 3 TO 4	[illegible]	[illegible]	[illegible]
E	[illegible]	[illegible] ADDED ITEM 7	[illegible]	[illegible]	[illegible]

ITEM	SYMBOL	DWG NO.	DESCRIPTION	QTY ASSY
1		CF-013324	BD FAB, MASTER	1
	P9601		CONN, BURNDY, MS19RM-61	1
	P3101		MS19RM-61	
	P701		MS19RM-61	1
	P3501		MS20RM-6	
	P501		MS20RM-61	1
	P2801		CONN, BURNDY MS26RM-61	1
2			STAT. SOFF AMATOM, [illegible]	2
3		(SEE NOTE 3)	CONTACT, COAX, [illegible]	1
4		(SEE NOTE 4)	CONTACT, COAX, BRAND), FEMALE	1
5			TUBING, SHRINK, [illegible]	2
6			SLEEVING, CLEAR THERMOSET [illegible]	A/R
7		AD-015061	COMPRESSION SPRING	







NOTES:
1) * = LATEST REVISION
2) ** = SCREW LENGTHS TO BE DETERMINED IN ACCORDANCE WITH DCS WORKMANSHIP MANUAL #AS-832011.

3) ITEM 3 CONSISTS OF THE FOLLOWING PARTS: AMDX60-1, AFD26L-1, AMDX8-055-1, YOC-074
4) ITEM 4 CONSISTS OF THE FOLLOWING PARTS: RCDX60-1, RMD-26L-1, RCDX8-055-1, YOC-074

REF	DESCRIPTION	QTY

GFD-13	DA-013976	1
PRODUCT	NEXT ASSEMBLY	QTY / ASSY

DATA CONTROL SYSTEMS, INC.

TITLE: BD ASSY, MASTER

TOLERANCES UNLESS OTHERWISE SPECIFIED
DECIMAL 3 PLACE ± .005
DECIMAL 2 PLACE ± .010
FRAC ± 1/64 ANG ± 0°30'
FLATNESS WITHIN ~ /IN
FRACTIONAL HOLES -0 + 1/64
NOTE BREAK ALL SHARP CORNERS .005" - .015"

DRWN DH 3/16/65
CHKD
PROJ ENG
CM ENG
SCALE FULL

DO NOT SCALE DRAWING
MAT'L
FINISH

CA - 013452 REV E

CA-013452 REV E

REV	DESCRIPTION	DATE	DWN	CHK	APP
C	CA 3410 RESTRUCTURED LATEST STDS DWG. WAS 'D' SIZE. (1 SH.)	7-25-66	DR		
D	CA 3425 CHG'D PER "AP" TO CENTRONICS	9/23/66	DR		
E	CA 3558 CHG'D CENTRON 203, 209 DCS MFG	1/24/67	DR		
F	CA 3550-3 CHG'D DIODE VALUE	4/4/67	DR		

NOTES:

1) * - LATEST REVISION
2) ** - SCREW LENGTHS TO BE DETERMINED IN ACCORDANCE WITH DCS WORKMANSHIP MANUAL AS-832011.
3) S.E. 2N3856A, 2N3855A, AND IGL64 ARE DIRECTLY INTERCHANGABLE.

REF.	DESCRIPTION	QTY
C213	CAP, CENTRON., 20V +80% -0 30μf	1
C214	DURMICA, DM-10, 130μμf	1
C215	↓ ↓ 22μμf	1
C216	GENT., BD-019132, 25V 30μf	1
C217	BT, RMC, 100V, .1μf	1
C218	GENT. BD-019132, 25V, 30μf	1
C219	SPRAGUE, 5C13, 25V, 1μf	1
C220	GENT. BD-019132, 25V 30μf	1
C221	↓ ↓ 25V 30μf	1
C222	↓ ↓ 25V 30μf	1
C223	BT, RMC, 100V, .1μf	1
C224	GENTRON., 20V +80% -10% 30μf	1
Q200	TRANS., G.E., 2N3856A	1
Q201	↓ ↓ 2N3856A	1
Q202	↓ ↓ 2N3856A	1
Q203	↓ ↓ 2N3856A	1
Q204	↓ ↓ 2N3856A	1
Q205	↓ ↓ 2N3856A	1
Q206	↓ ↓ 2N3856A	1
Q207	↓ ↓ 2N3856A	1
Q208	↓ ↓ 2N3856A	1
L200	COIL, DELEVAN, 2500 -28 IMH	1
L201	↓ ↓ IMH	1
L202	↓ ↓ IMH	1

T

REV F

R229	RES, AB, CB, 1/4W, 10%, 10K	1
R230	↓ ↓ 1K	1
R231	ELEC., MFSC-D, 1/4W, FA	1
R232	AB, CB, 1/4W, 10% 0K	1
R233	↓ ↓ 10K	1
R234	↓ ↓ 2.2K	1
CR200	DIODE, CLEVITE, CTP700A	1
CR201	↓ ↓ CTP700A	1
CR202	↓ ↓ GE 2B12	1
CR203	↓ ↓ ↓	1
CR204	↓ ↓ ↓	1
CR205	↓ ↓ ↓	1
CR206	↓ CONT. DEV., IN3067	1
CR207	↓ ↓ IN3067	1
CR208	↓ ↓ IN3067	1
CR209	↓ ↓ IN3067	1
C200	CAP, CENTRON., 20V +80% -0 30μf	1
C201	GENT. BD-019132, 25V, 30 μf	1
C202	SPRAGUE, 5C13, 25V, 1μf	1
C203	GENTRON, 20V +80% -0 30μf	1
C204	DURMICA, DM-10, 22μμf	1
C205	GENT. BD-019132, 25V 30μf	1
C206	DURMICA, DM-10, 12μμf	1
C208	DURMICA, DM-10, 93μμf	1
C209	GENTRON, 20V +80% -0 30μf	1
C210	GENT. BD-019132, 25V, 30μf	1
C211	SPRAGUE, 5C11, 25V, .47μf	1
C212	↓ BT, RMC, 100V, .1μf	1

SEE SHEET 2 OF 2 FOR ASS'Y. DWG

ITEM	SYMBOL	DWG NO	DESCRIPTION	QTY PER ASSY
1		CF-013580	BD. FAB, LIMITER	1
2		BD-013319	BRKT. RIGHT	1
3		BD-013320	BRKT. LEFT	1
4	**	AS-826028 #2-56	SCREW #2-56 PHMS	2
5			CONN. BURNDY, MS14PM-61	1
6		AS-826018 #02	WASHER, SPLIT, #2	2
7		AS-826017 #02	WASHER, #2	2
8		BD-014206	GUIDE RAIL	1
9			1/4 TRANSFER TAPE #V-9164	A/R
10			PAD, TRANS. THERM-A-CON 277-2N WHITE	A/R
11			JUMPER, #22 BUSS WIRE	A/R
	R200		RES, AB, CB, 1/4W, 10%, 3.3K	1
	R201		↓ ↓ 6.8K	1
	R202		ELEC., MFSC-D, 1/4W, FA	1
	R203		AB, CB, 1/4W, 10%, 1.2K	1
	R204		↓ ↓ 2.2K	1
	R205		ELEC., MFSC-D, 1/4W, 825Ω	1
	R206		↓ ↓ 287Ω	1
	R207		↓ ↓ 23.7K	1
	R208		AB, CB, 1/4W, 10% 470Ω	1
	R209		↓ ↓ 4.7K	1
	R210		ELEC., MFSC-D, 1/4W, 750Ω	1
	R211		↓ ↓ 10K	1
	R212		↓ ↓ FA	1
	R213		ELEC., MFSC-D, 1/4W, 2.15K	1
	R214		↓ ↓ 1.96K	1
	R215		AB, CB, 1/4W, 10% 100Ω	1
	R216		ELEC., MFSC-D, 1/4W, 1.96K	1
	R217		↓ ↓ 681Ω	1
	R218		AB, CB, 1/4W, 10% 180Ω	1
	R219		↓ ↓ 4.7K	1
	R220		ELEC., MFSC-D, 1/4W, 511Ω	1
	R221		↓ ↓ 10K	1
	R222		AB, CB, 1/4W, 10% 100Ω	1
	R223		ELEC., MFSC-D, 1/4W, 1.47K	1
	R224		AB, CB, 1/4W, 10% 100Ω	1
	R225		↓ ↓ 100Ω	1
	R226		ELEC., MFSC-D, 1/4W 46.4Ω	1
	R227		AB, CB, 1/4W, 10% 1.5K	1
	R228		↓ ↓ 100Ω	1

GFD-13	BA-013642	1
FIRST PRODUCT	NEXT ASSEMBLY	QTY. / ASSY.

DATA CONTROL SYSTEMS, INC.

TITLE: BD ASS'Y., LIMITER & INPUT METER

TOLERANCES UNLESS OTHERWISE SPECIFIED:
DECIMAL - 3 PLACE ± .005
DECIMAL - 2 PLACE ± .010
FRAC. ± 1/64 ANG. ± 0°30'
FLATNESS WITHIN .../IN.
FRACTIONAL HOLES .0 +.1/64
NOTE: BREAK ALL SHARP CORNERS .005" - .015"
SURFACE ROUGHNESS NOT TO EXCEED ...

DWN	DR	DATE 7/25/66
CHKD		8/17/66
ENG		8/18/66
APP.		8/19/66
SCALE	NONE	

DO NOT SCALE DRAWING
MAT'L
FINISH

TA-013506 REV. F

SHEET 1 OF 2

REV	DESCRIPTION	DATE	DWN	CHK	APP
C	CA3410 REDRAWN TO LATEST STDS. ON 'D' SIZE (15H.)	7/25/66	CR		
D	CA-3410-3 CHG. PER ECO 1-3	9/1/66	CR		
E	CA-3550-3 ADD CR201, 203, 204, 205 PER ECO 1-5	11/14/67	CR		
F	CA-3550-3 CHG. SR204 FROM 1.96K TO 2.15K	4/23/68	CR		

REF	DESCRIPTION	QTY

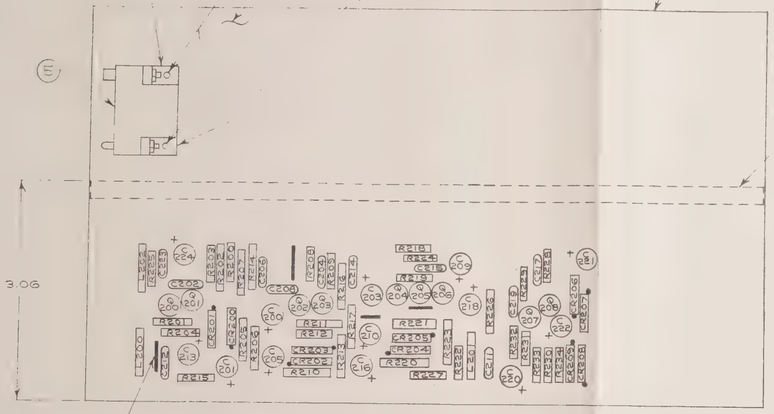
REV	ITEM	SYMBOL	DWG. NO.	DESCRIPTION	QTY / ASSY
T					
F					

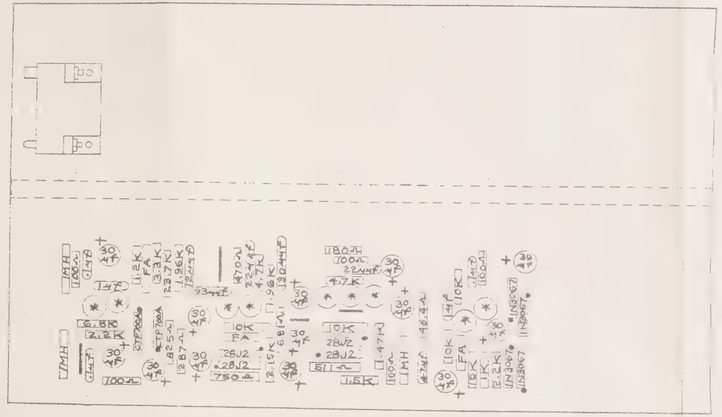
STAMP D.C.S. PART NO. IN 1/8 HIGH CONTRASTING CHARACTERS APPROX. AS SHOWN

BOND ITEM 8 ON COPPER SIDE WITH ITEM 9

3.06

TYP.





*-2N3856A AND ITEM 10

•-DENOTES CATHODE END

SEE SHEET 1 OF 2 FOR PARTS LIST & NOTES.

GFD-13	BA-013642	1
FIRST PRODUCT	NEXT ASSEMBLY	QTY / ASSY

DATA CONTROL SYSTEMS, INC.

TITLE: BD ASS'Y., LIMITER & INPUT METER

TOLERANCES: UNLESS OTHERWISE SPECIFIED
DECIMAL - 3 PLACE ± .005
DECIMAL - 2 PLACE ± .010
FRAC ± 1/64 ANG ± 0°30'
FLATNESS WITHIN ~ /IN
FRACTIONAL HOLES Ø .+ 1/64
NOTE: BREAK ALL SHARP CORNERS .005", .015" SURFACE ROUGHNESS NOT TO EXCEED ✓

DWN CR 7/25/66
CHKD 8/17/66
ENG 8/17/66
APP 8/24/66

DO NOT SCALE DRAWING
MAT'L —
FINISH —
SCALE NONE

TA-013506 REV F

SHEET 2 OF 2

REV.	DESCRIPTION	DATE	DWN.	CHK.	APP.
L	CA 3410 REDRAWN TO LATEST STDS DWG WAS 'S' SIZE (9H)	8/8/66	DR	[illegible]	[illegible]
M	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N	ADDED TERM. WEE 3H-3513	11/66	FE	[illegible]	[illegible]
P	* 3503-2 DELETED 3-4-8 & 18	6/4/67	FC	[illegible]	[illegible]
Q	14-3550-6480 (REF. 3H, 3C, 3K) NFG.	1/6/69	DE	[illegible]	[illegible]
R	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
S	CA-3608 CHGD TRANS Q414	MFG.	[illegible]	[illegible]	[illegible]
T	CA-3550-3 CHGD DIODE VALUES	MFG.	[illegible]	[illegible]	[illegible]
U	CA-3550-2 CHGD REF. VALUES	MFG.	[illegible]	[illegible]	[illegible]
V	CA-3209-2 ADD C404	8-6-68	[illegible]	[illegible]	[illegible]
W	CA-4851 CHGD R410 & R531	2-28-69	ER	WR	WR
Y	CA-4905 CHGD R315	5/21/69	JEH	WR	WR
Z	CA-3040-1 ADD NOTE #7	5-23-69	GOD	WR	WR
AA	CA-5086, CHGD TRANS PART	6-2-69	GOD	WR	WR

REF	DESCRIPTION	QTY

NOTES.

1) * - LATEST REVISION
2) * * - SCREW LENGTHS TO BE DETERMINED IN ACCORDANCE WITH DCS WORKMANSHIP MANUAL AS-832011
3) G.E. 2N3855A, 2N3855A, & IGL64 ARE DIRECTLY INTERCHANGABLE.
4) ITEM 11 TO MOUNT UNDER TRANS Q500 THRU Q504, Q507 THRU Q517, Q520, Q525, Q528, Q529, Q400, Q403, Q404, Q405, Q406, Q408 THRU Q414, Q300 THRU Q304.
5) ITEM 12 TO MOUNT UNDER TRANS. Q526, Q527.
6) ITEM 13 TO MOUNT UNDER TRANS. Q505, Q506, Q518, Q519, Q521, Q522, Q523, Q524, Q401, Q402, Q407.
7) TRANS Q528 & Q529 ARE FACTORY ADJUST FOR TEMP. COMPENSATION AND MAY BE REMOVED AND REPLACED WITH A JUMPER.

Q510	TRANS, G.E.	2N3855A	1
Q511		2N3855A	1
Q512		2N3855A	1
Q513		2N3855A	1
Q514		2N3855A	1
Q515		2N3855A	1
Q516		2N3856A	1
Q517		2N3856A	1
Q518	MOTOROLA,	SPS1503	1
Q519		SPS1503	1
Q520	G.E.	IGL64A	1
Q521	FAIRCHILD	2N4250	1
Q522	FAIRCHILD	2N4250	1
Q523	MOTOROLA,	SPS1503	1
Q524		SPS1503	1
Q525	G.E.	2N3856A	1
Q526	FAIRCHILD,	2N3638	1
Q527		2N3638	1
Q528	G.E.	2N3855A	1
Q529		2N3856A	1
Q530	TRANS, G.E.	2N3856A	1
Q531	G.E.	2N3856A	1

CR404	DIODE, CONT DEV.,	IN3067	1
CR405		IN3067	1
CR406		IN3067	1
CR407		IN708	1
CR500		IN3067	1
CR501		IN3067	1
Q300	TRANS., G.E.,	2N3856A	1
Q301		2N3856A	1
Q302		2N3856A	1
Q303		2N3856A	1
Q304		2N3856A	1
Q400		2N3391A	1
Q401	MOTOROLA,	SPS1503	1
Q402		SPS1503	1
Q402A		SPS1503	1
Q403	G.E.,	2N3856A	1
Q404		2N3856A	1
Q405		2N3391A	1
Q406		2N3391A	1
Q407	FAIRCHILD,	2N4250	1
Q408	G.E.,	2N3856A	1
Q409		2N3856A	1
Q410		2N3856A	1
Q411		2N3856A	1
Q412		2N3856A	1
Q413		2N3856A	1
Q414		2N3856A	1
Q500		2N3856A	1
Q501		2N3856A	1
Q502		2N3856A	1
Q503		2N3856A	1
Q504		2N3856A	1
Q505	MOTOROLA,	SPS1503	1
Q506		SPS1503	1
Q507	G.E.,	2N3856A	1
Q508		2N3856A	1
Q509		2N3856A	1

R522	RES, WLCG0-T2, 1/4W, 1%,	10K	1
R523	ELEC. MFSC-D, 1/4W, 1%	3.3K	1
R524	WLCG0-T2, 1/4W, 1%	5.11K	1
R525	AB, CB, 1/4W, 10%	1K	1
R526	WLCG0-T2, 1/4W, 1%	12.1K	1
R527		33.2K	1
R528		301K	1
R529		619Ω	1
R530		17.8K	1
R531	AMPHENOL, 3500	2K TU	1
R532	WLC 60 T2, 1%	26.7K	1
R533	ELECT. MFSC-D, 1%	10K	1
R534		10K	1
R535	AB, CB, 1/4W, 10%	10M	1
C300	CAP, GENT, 101 DDS, 20%, +20% -0,	30μf	1
C301	GENT, BD-014132,	25V, 30μf	1
C302		25V, 30μf	1
C303		25V, 30μf	1
C400	GENT, BD-014132,	25V, 30μf	1
C401	ILL, SMTU, 450,	50V	1
C402	GENT, BD-014132,	25V, 30μf	1
C403	DURMICA, DM-10,	10 μμf	1
C405	GENT, BD-0-14132,	25V, 30μf	1
C406	GENT, BD-014133,	50V, 15μf	1
C407	DURMICA, DM-10,	6.8μμf	1
C408	BT, RM6,	1 μf	1
C409	SPRAGUE 10D683X9075M4,	75V, 33μf	1
C410	GENT, BD-014132,	25V, 30μf	1
C600	DURMICA, DM-10,	470 μμf	1
CR300	DIODE, GE,	8BJ2	1
CR301			1
CR302			1
CR303			1
CR400	CONT. DEV.,	IN3067	1
CR401		IN3067	1
CR402		IN3067	1
CR403		IN3067	1

R406	RES, ELEC MFSC D, 1/4W, 1%	4.64K	1
R407		110K	1
R408		21.5K	1
R409		7.5K	1
R410		562K	1
R411	AB, CB, 1/4W, 10%	2.2K	1
R412		5.6K	1
R413	ELEC. MFSC-D, 1/4W, 1%	147K	1
R414	AB, CB, 1/4W, 10%	1K	1
R415	ELEC. MFSC-D, 1/4W, 1%	2.5K	1
R416		46.4K	1
R417	AB, CB, 1/4W, 10%	100K	1
R418	ELEC., MFSC-D, 1/4W, 1%	46.4K	1
R419		5.11K	1
R420	AMPHENOL, 3500	2K TU	1
R421	AB, CB, 1/4W, 10%	22K	1
R422		100Ω	1
R423		47Ω	1
R500	WLC 30-T2, 1/4W, 1%	2.1K	1
R501		5.11K	1
R502	AB, CB, 1/4W, 10%	10K	1
R503	ELEC., MFSC-D, 1/4W, 1%	10K	1
R504	WLCG0-T2, 1/4W, 1%	5.62K	1
R505	ELEC. MFSC-D, 1/4W, 1%	100K	1
R506		1K	1
R507	WLCG0-T2, 1/4W, 1%	14K	1
R508	ELEC., MFSC-D, 1/4W, 1%	147K	1
R509	WLCG0-T2, 1/4W, 1%	10K	1
R510		10K	1
R511	ELEC., MFSC-D, 1/4W, 1%	147K	1
R512	WLCG0-T2, 1/4W, 1%	14.0K	1
R513	ELEC. MFSC-D, 1/4W, 1%	100K	1
R514	WLCG0-T2, 1/4W, 1%	5.62K	1
R515	ELEC., MFSC-D, 1/4W, 1%	10K	1
R516	AB, CB, 1/4W, 10%	100K	1
R517	ELEC., MFSC-D, 1/4W, 1%	1K	1
R518	WLC60-T2, 1/4W, 1%	14K	1
R519		13.3K	1
R520	ELEC., MFSC-D, 1/4W, 1%	100K	1
R521	WLCG0-T2, 1/4W, 1%	10K	1

ITEM	SYMBOL	DWG NO.	DESCRIPTION	QTY/ASSY
1		OF-D-3414	BD FAB, VCO	1
2			JUMPER #22 BUSS WIRE	A/R
3			CONN. BURNDY MRB6PM-G1	1
4		BD-013320	BRACKET, LEFT	1
5		AS-882018 #02	WASHER, SPLIT, #2	2
6		AS-882017 #02	WASHER, #2	2
7	* *	AS-882026 #2-56	SCREW, #2-56 PHMS	2
8		BD-013319	BRACKET, RIGHT	1
9	DS400		DIFFUSE LAMP, BALL END, RED, CAT-550	1
10			#82 LAMP	1
11			CAD TRANS, THERMALLOY 2N3638 MMBT 5179	A/R
12			CAD TRANS, MOTOROLA 2N4250	A/R
13			CAD TRANS, ROSE #10042	A/R
14			CAD TRANS, AD-236/13-A	A/R
15		AS-882011-A-2	BEARING BUTTON	2
	R300		RES ELEC MFSC-D 1/4W 1%	36.3K
	R301			121K
	R302			46.4K
	R303		AB CB 1/4W, 10%	1K
	R304			4.7K
	R305		ELEC MFSC-D 1/4W 1%	562K
	R306		AB CB, 1/4W, 10%	22K
	R307			5.6K
	R308			1.8K
	R309			1K
	R310		ELEC., MFSC-D 1/4W 1%	31.6K
	R311			549Ω
	R312			249Ω
	R313			2.21K
	R314			4.42K
	R315		AB, CB 1/4W, 10%	2.2K
	R316			4.7K
	R317			100K
	R400		ABCB 1/4W 10%	100K
	R401			22K
	R402			2.2K
	R403		ELEC MFSC D 1/4W 1%	26.1K
	R404			14.7K
	R405			5.62K

SEE SHEET 2 OF 2 FOR ASS'Y. DWG.

GFD-13	BA-013643	1
FIRST PRODUCT	NEXT ASSEMBLY	QTY/ASSY

DATA CONTROL SYSTEMS, INC.

TITLE: BD ASS'Y, VCO

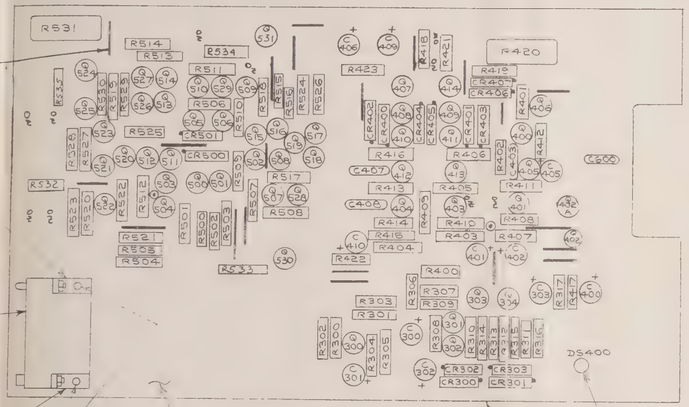
TOLERANCES: UNLESS OTHERWISE SPECIFIED
DECIMAL - 3 PLACE ± .005
DECIMAL - 2 PLACE ± .010
FRAC. ± 1/64 ANG. ± 0°30'
FLATNESS WITHIN .001 IN.
FRACTIONAL HOLES Ø .4 1/64
NOTE BREAK ALL SHARP CORNERS .005", .015" SURFACE ROUGHNESS NOT TO EXCEED

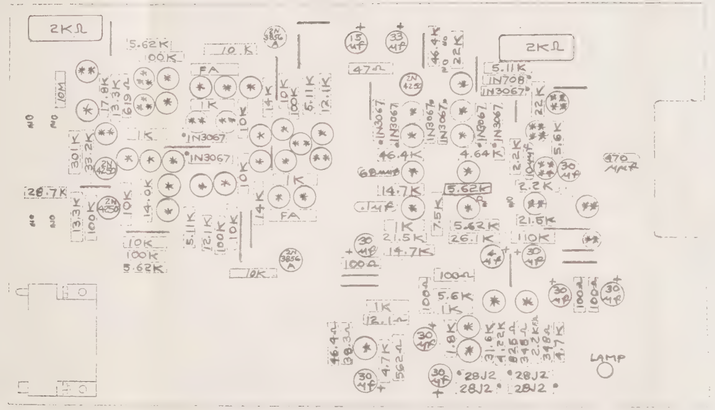
		DATE
DWN.	DR	7/12/66
CHKD.	[illegible]	6/17/66
ENG.	[illegible]	5/12/66
APP.	[illegible]	5/12/66
SCALE	NONE	

DO NOT SCALE DRAWING
MAT'L
FINISH
SIZE: A
TA-013547 M
SHEET 1 OF 2

REV.	DESCRIPTION	DATE	DWN	CHK	APP
L	CA 3410. REDRAWN TO LATEST STDS. DWG WAS G SIZE (1 SH.)	8/2/66	DR		
M	CA-3455-CHG'D. CAP. VALUES	9/6/66	DR		
N	REVISIED PER CA-3505	11/14/66	P.D.		
P	CA-3505-1 DELETED R818 & C304	1/4/67	P.D.		
Q	CA-3550-1 ADD'D CR 300, 301, 302, 303 & CHG'D R315	2/21/67	P.D.		
R	CA-3584 CHG'D C405 TO 25V	7/14/67			
S	CA-3650-3 CHG'D DIODE VALUES	4/25/67	P.D.		
T	CA-3550-2 CHG'D RES. VALUES	4/24/67	P.D.		
U	CA-4485 CHG. POLARITY OF C405	9/23/68	JEH		
V	CA-3209-2 ADD C404	8-6-68	JEH		
W	CA-4857-CHG'D R420 & R531	12/19/68	JEH		
Y	CA-4905 CHG'D R315	12/19/68	JEH		
Z	CA-3040-1, ADD NOTE #7	5-23-69	GCD		
AA	CA-3085, CHGD TRANS PAD	6-2-69	GCD		

REF.	DESCRIPTION	QTY





*- 2N3856A AND ITEM 11.
**- SPS 1803 AND ITEM 13.
***- 2N3638 AND ITEM 12.
****- 2N3391A AND ITEM 11.

●- DENOTES CATHODE END.

⊙ INSTALL ITEM 15 APPROX. AS SHOWN, SEE SHEET 1 OF 2 FOR PARTS LIST & NOTES.

REV.	ITEM	SYMBOL	DWG. NO.	DESCRIPTION	QTY. ASSY.
T					

DATA CONTROL SYSTEMS, INC.

TITLE: BD ASS'Y, VCO

TOLERANCES: UNLESS OTHERWISE SPECIFIED
DECIMAL - 3 PLACE ± .005
DECIMAL - 2 PLACE ± .010
FRAC. ± 1/64 ANG. ± 0°30'
FLATNESS WITHIN .../IN
FRACTIONAL HOLES Ø ± 1/64
NOTE- BREAK ALL SHARP CORNERS .005"-.015"
SURFACE ROUGHNESS NOT TO EXCEED ...

	DWN.	DATE
	DR	8/12/66
CHKD.		8/17/66
END.		8/18/66
APP.		8/19/66

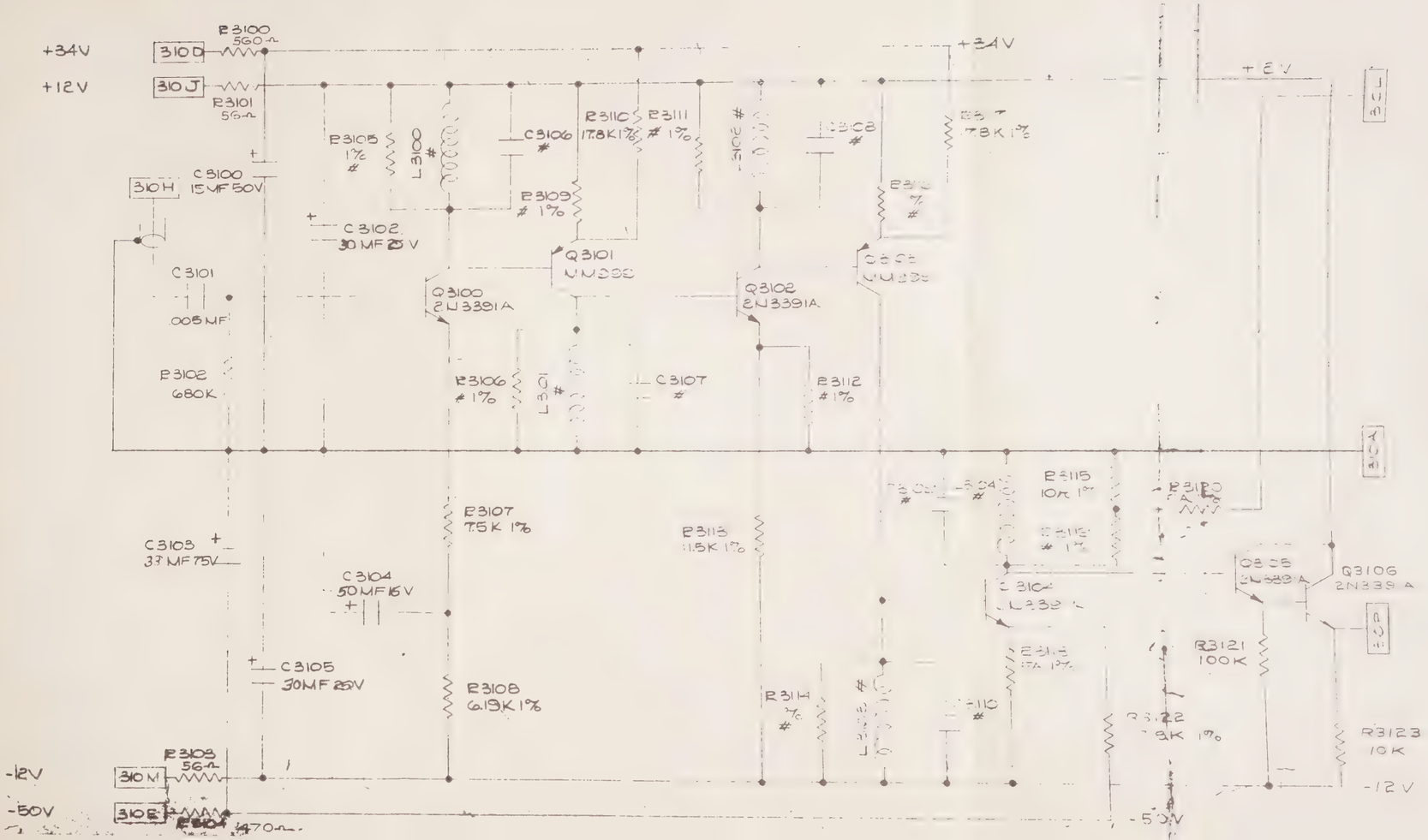
DO NOT SCALE DRAWING
MAT'L —
FINISH —
SCALE NONE.
DWG. NO. TA-013547AA
REV. T
SHEET 2 OF 2

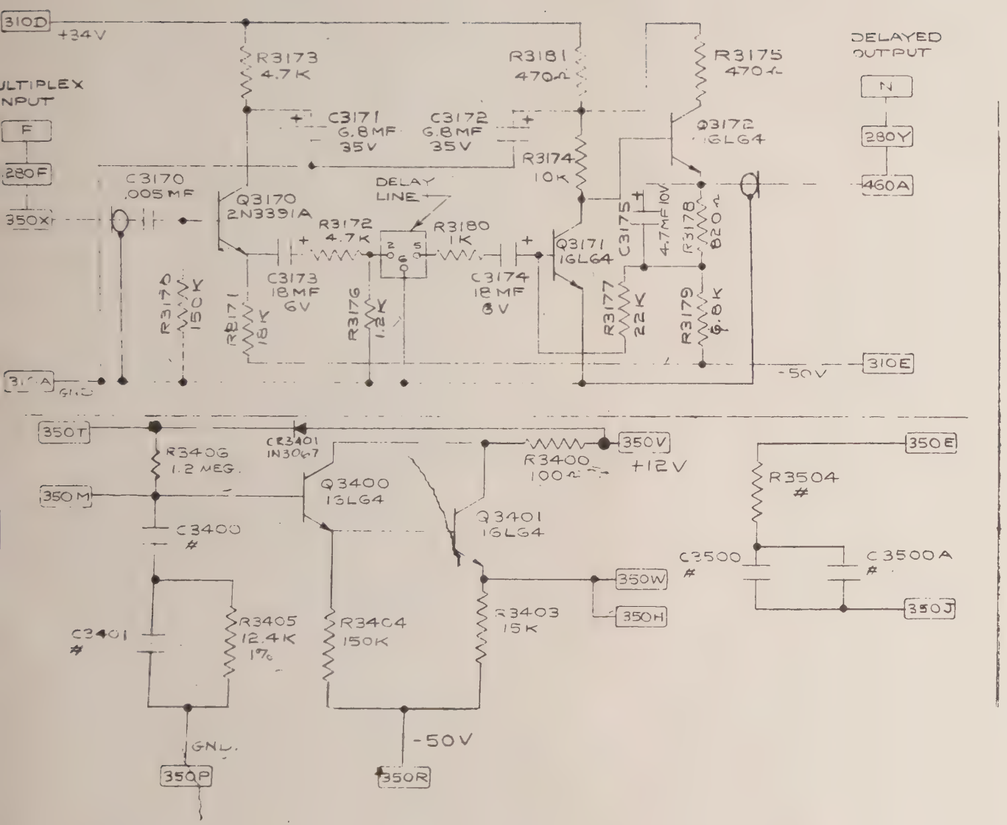
GFD-13	BA-013643	1
FIRST PRODUCT	NEXT ASSEMBLY	QTY. ASSY.

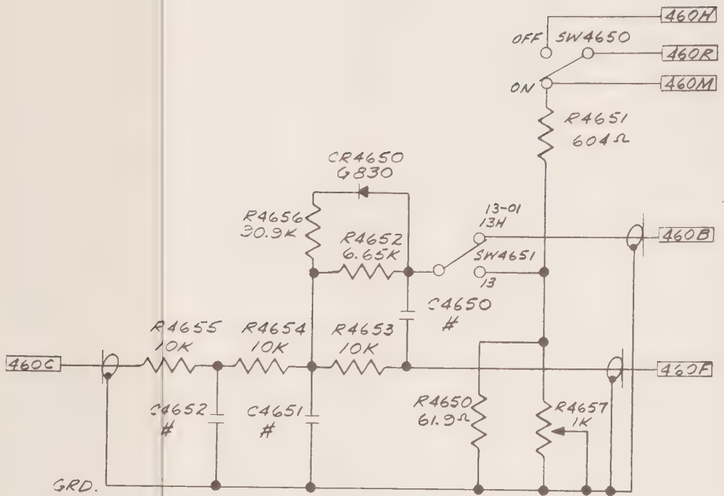
REV.	DESCRIPTION	DATE	DWN.	CHK.	APP.
B	CA3196, REVISED LOW PASS FILTER SECTION. CA3196-1, CHANGED R3175, R3178, R3179 & ADDED NOTE 4.	6/13/66	DR		
C	CA3158-1. ADDED R3406 +350T	7/20/66	DR		
D	CA3515 - ADDED CR3101	12/67			
E	CA-3519-1 CHGD CAP. VALUES	9/1/1			
F	CA-3519 2 CHGD CAP VALUE	8/29/			

NOTES:

1. GE1SLG4 IS DIRECTLY INTERCHANGABLE WITH GE2N3855A AND GE 2N3856A.
2. THIS IS AN ADDENDUM SHEET TO EW-013819 (SCHEMATIC OF GFD-13)
3. # - SENSITIVE COMPONENTS.
4. THIS SCHEMATIC APPLIES TO ALL GFD-13/RTU UNITS 100 Kc AND BELOW, WITH SERIAL NO. SUFFIX "A". FOR UNITS ABOVE 100Kc, SEE GW-015117







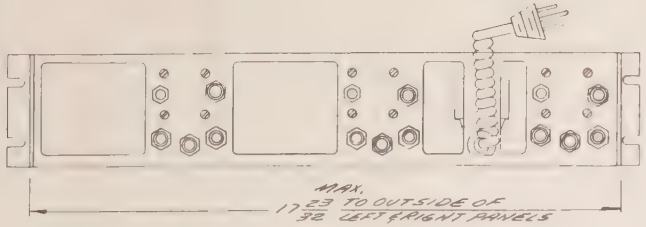
L.P.F.

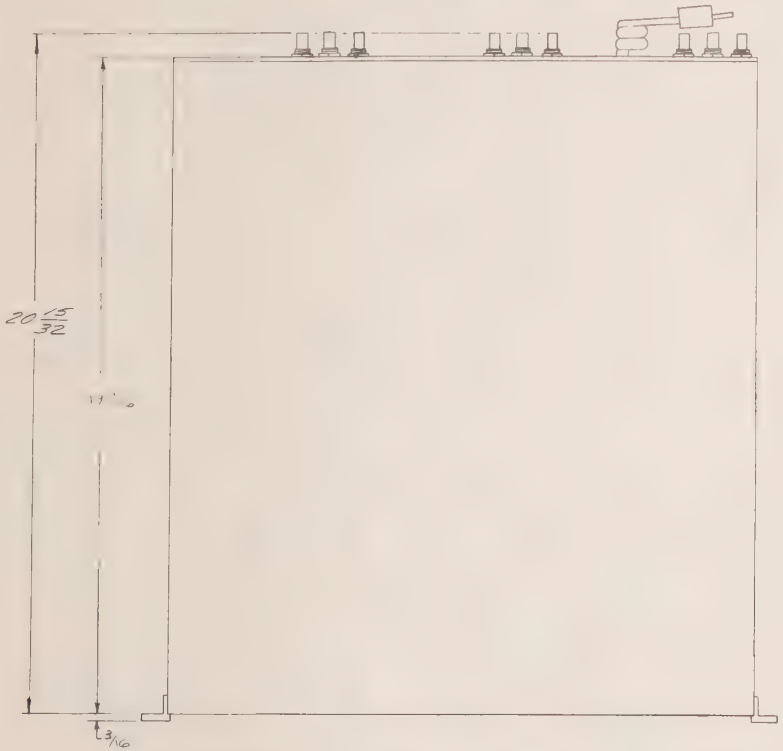
RES. ARE W.L. RN60C, ¼W, 1%

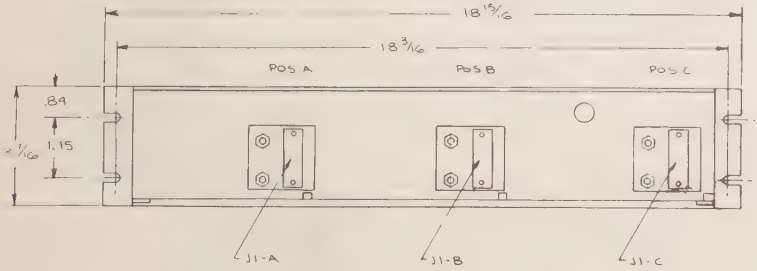
#CAR ARE FREQ. SENS.

DATA CONTROL SYSTEMS, INC.	TITLE: SCHEMATIC REF TUNING UNIT	
TOLERANCES: UNLESS OTHERWISE SPECIFIED DECIMAL - 3 PLACE ± .005 DECIMAL - 2 PLACE ± .010 FRAC. ± 1/64 ANG. ± 0°30' FLATNESS WITHIN ~/IN. FRACTIONAL HOLES -0. + 1/64 NOTE: BREAK ALL SHARP CORNERS .005"-.015"	DWN RTW 12/4/68 CHKD 12/4/68 PROJ ENG 13/6/68 CH ENG 14/6/68 SCALE ~	DO NOT SCALE DRAWING GFD-13/RTU ~ RW-014010 REV G

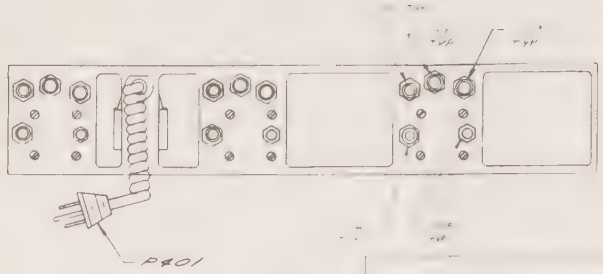
REVISIONS				
SYM	DESCRIPTION	DATE	BY	CHK	APR
B	ECR) REV TABLE ADDED 7/7/72 ECR 2371	7/6/72			
C	ECR ADDED BNC J109	7/6/72			
D	CR 2371: CHANGED J-CONN. FROM SMSW TWO GV-06 PINS				
E	CR-2371A				

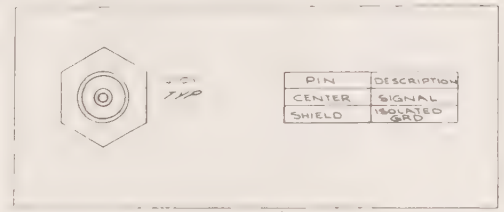




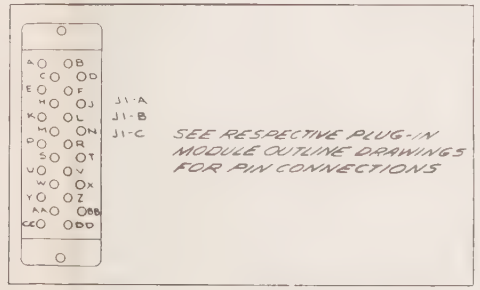


REAR VIEW





PIN	DESCRIPTION
CENTER	SIGNAL
SHIELD	ISOLATED GRD



SEE RESPECTIVE PLUG-IN MODULE OUTLINE DRAWINGS FOR PIN CONNECTIONS

NO	CONNECTOR	MATING CONNECTOR	NO	FUNCTION
J101	DAGE 30728-1	UG-88C/U	P101	INPUT
J102	DAGE 30728-1	UG-88C/U	P102	WOW & FLUTTER INPUT *
J103	DAGE 30728-1	UG-88C/U	P103	VCO OUTPUT
J104	DAGE 30728-1	UG-88C/U	P104	GFD REMOTE OFFSET (SHORTED BNC)
J105	DAGE 30728-1	UG-88C/U	P105	SERVO REFERENCE
J201	DAGE 30728-1	UG-88C/U	P201	INPUT TAPE SPEED SIG.
J202	DAGE 30728-1	UG-88C/U	P202	WOW & FLUTTER INPUT (MONITOR BNC)
J203	DAGE 30728-1	UG-88C/U	P203	VCO OUTPUT
J204	DAGE 30728-1	UG-88C/U	P204	REFERENCE OUTPUT (SHORTED BNC)
J205	DAGE 30731-1	UG-88C/U	P205	T & C SIGNAL
J1	DAGE 30728-1	UG88C/U	P101	INPUT
J1-C	" "	" "	P202	WOW & FLUTTER INPUT (MONITOR BNC)
J1-B	" "	" "	P203	VCO OUTPUT
J1-A	" "	" "	P204	REFERENCE OUTPUT (SHORTED BNC)
J205	" 30731-1	" "	P205	T & C SIGNAL
~		GRAYHILL 30M16P OR EQUAL MATED W/ CABLE CC40	P401	POWER
J1-A	BURNDY, MS 2GRM-1	BURNDY, MS 2G PM-1	P1-A	POS A
J1-B	BURNDY, MS 2GRM-1	BURNDY, MS 2G PM-1	P1-B	POS B
J1-C	BURNDY, MS 2GRM-1	BURNDY, MS 2G PM-1	P1-C	POS C

* ATUC ONLY, SEE DEMOD

NOTE
1. * WHEN WOW & FLUTTER INPUT IS NOT USED, USE SHORTED BNC IN GMH-13
2. ** THE GFD-13/RTUC REQUIRES AN EXTERNAL DELAY LINE FOR TAPE SPEED COMPENSATION.

DO-013508 F

DATA-CONTROL SYSTEMS, INC.

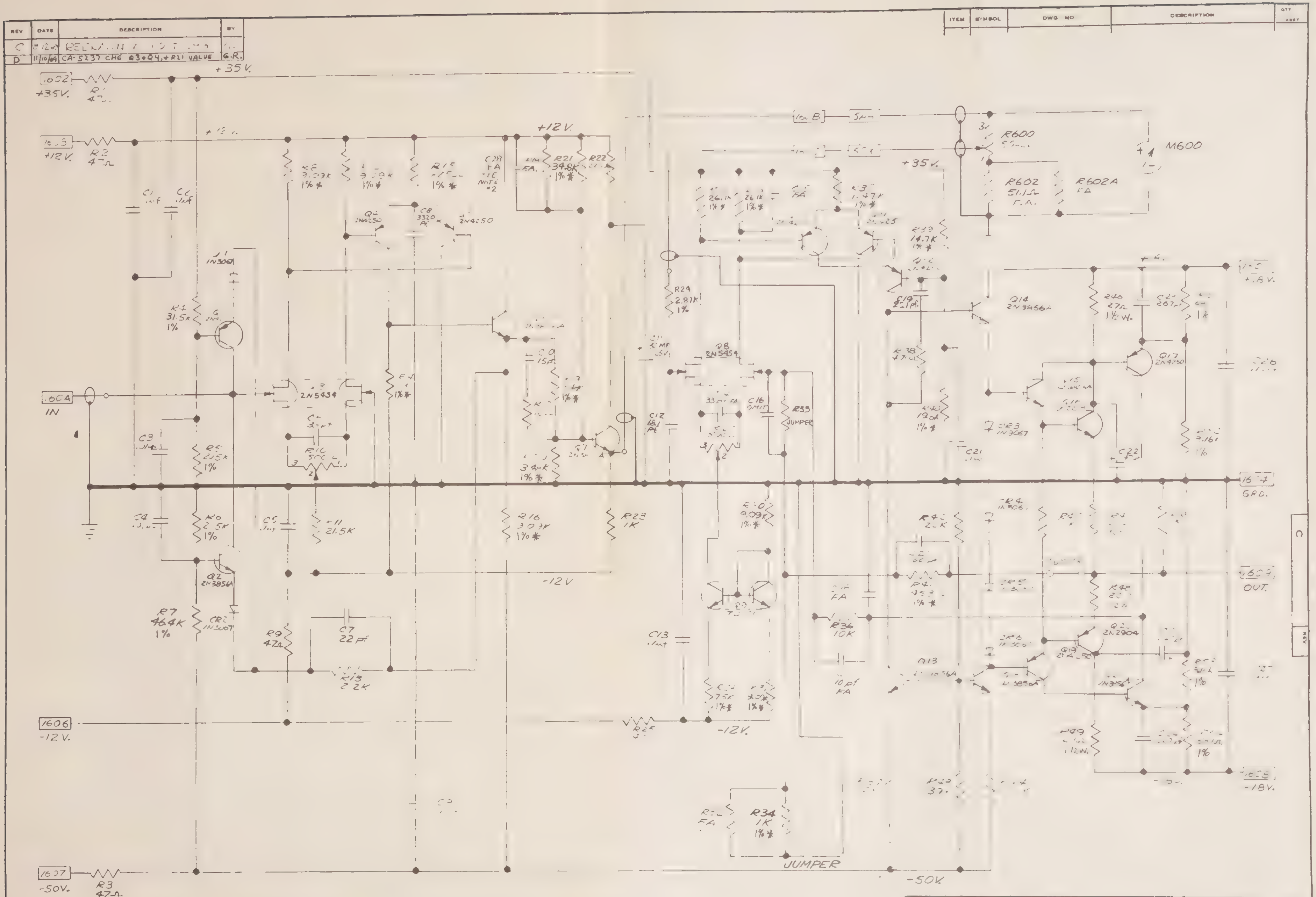
TITLE: OUTLINE DWG, GMH-13

TOLERANCES: DEC ± .005, FRAC ± 1/32, ANGL ± 0° 30'

SCALE: HALF | DATE: 7/6/72 | DO NOT SCALE DRAWING

DRAWN | CHKD | ENGR | MFG | QA | APPD | DATE | FINISH

GMH-13 | PRODUCT | NEXT ASSY | GMH-13 | DO-013508 | REV C



REV | DATE | DESCRIPTION | BY
D 11/10/69 CA-5237 CHG Q3+Q4,+R21 VALUE G.R.
ITEM | SYMBOL | DWG NO | DESCRIPTION | QTY ASSY
+35V.
+35V.
R1
+12V.
R2
+12V.
C1
C2
R6 1% *
1% *
R15 1% *
C28 FA SEE NOTE #2
R21 34.8K 1% *
R22
Q4 2N4250
C8 3320 pf
2N4250
1N3067
R4 31.5K 1%
IN
2N5454
C3
R5 1%
R10
FA 1% *
C10
R16 1% *
R23 1K
R24 2.87K 1%
Q8 2N5454
C16 OMIT
R39 JUMPER
C12
R600
M600
R602 51.1Ω F.A.
R602A FA
+35V.
R33 14.7K 1% *
C19
Q14 2N3456A
Q17 2N4250
R38
R40 1% *
CR3 1N3067
C21
C22
GRD.
C4
C5
R11 21.5K
Q2 2N3856A
R7 464K 1%
CR2 1N3067
R9 47Ω
C7 22 pf
R13 2.2K
-12V
C13
-12V.
R36 10K
10 pf FA
Q13
Q19
2N2904
R49
OUT.
-18V.
1606 -12V.
1607 -50V.
R3 47Ω
R34 1K 1% *
JUMPER
-50V.

NOTES:

1. UNLESS OTHERWISE SPECIFIED ALL RESISTORS ARE 1/4 W. 10%
   * = TEMPERATURE COEFFICIENT ± 50 PPM/°C.
2. CAP. C28 NOT TO EXCEED 20 pf.

REF	DESCRIPTION	QTY

GFD-13-01	
PRODUCT	NEXT ASSEMBLY

DATA CONTROL SYSTEMS, INC.

TOLERANCES UNLESS OTHERWISE SPECIFIED
DECIMAL 3 PLACE ± .005
DECIMAL 2 PLACE ± .01
FRAC ± 1/64 ANG ± 0°30'
FLATNESS WITHIN IN
FRACTIONAL HOLES +.0 +1/64
NOTE: BREAK ALL SHARP CORNERS .005 .015

DWN
CHKD 10/30/69
ENG 10/30/69
SCALE

DO NOT SCALE DRAWING

MAT'L

FINISH

REV D

APPLICATION	
NEXT ASSY	USED ON
	GFD-13-01

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
C	CA-5237 CHG. COMP. VALVE + REDRAW	11/10/69	GR

NOTES:

1. ALL ELECTRA RESISTORS ARE MF5C-D.
2. ALL .1uF RMC CAPACITORS ARE TYPE BT.
3. ITEM #8 CONSISTS OF THE FOLLOWING;
   PARTS RMDX60-1, RFD26L-1, RMDXB-055-1, YOC-074.
4. ITEM #9 CONSISTS OF THE FOLLOWING PARTS;
   RMD 26L-1, RCDX-B-055-1, YOC-074.
5. CAP. C28 NOT TO EXCEED 20 pf. (F.A.)

REV																									
SHEET																									
REV																									
SHEET																									
REV. STATUS OF SHEETS	REV	C	C	C	C	C	C																		
	SHEET	1	2	3	4	5	6																		

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONS ±
DECIMALS ±
ANGLES ±

MATERIAL:

DRAWN L. GASPAR
CHECKED GR
PROJ ENG
APPROVED EPJ.
APPROVED
APPROVED
APPROVED 11/10/69 DATE

DATA-CONTROL SYSTEMS, INC.
DANBURY, CONN.

BOARD ASS'Y. LOW PASS AM P.

SIZE	CODE IDENT NO		
A	08539	A-018203	C

SCALE ~ GFD-13-01 SHEET 1 OF 6

ITEM	SYMBOL	PART NO.	DESCRIPTION		REV. QTY REQ'D
	R37		RESISTOR AB, CB, 1/4W	10K	1
	R38		RESISTOR AB, CB, 1/4W	470Ω	1
	R39		RESISTOR WL60-T2 1%	14.7K	1
	R40		↓	19.6K	1
	R41		RESISTOR WL60-T2 1%	10K	1
	R42		RESISTOR AB, CB 1/4W	22K	1
	R43		↓	39K	1
	R44		↓	10K	1
	R45		RESISTOR AB, CB, 1/4W	1K	1
	R46		RESISTOR MEPCO P90 1%	27Ω	1
	R47		RESISTOR AB, EB 1/2W	22Ω	1
	R48		RESISTOR AB, EB, 1/2W	22Ω	1
	R49		RESISTOR MEPCO P90 1%	27Ω	1
	R50		RESISTOR AB, CB 1/4W	1K	1
	R51		RESISTOR ELECTRA 1%	681Ω	1
	R52		↓	3.16K	1
	R53		↓	3.16K	1
	R54		RESISTOR ELECTRA 1%	681Ω	1
	R55		RESISTOR OPEN		1
10			TUBING, SHRINK#N-187-2 THOMAS&BETTS		3
1		DF-017624	BOARD FAB		1
2			JUMPER #22AWG BUSS WIRE		A/R
			TEFLON SLEEVING		A/R
3			HEATSINK, WAKEFIELD NE207		2
4			HEATSINK, BIRCHER 3AL-669-3B		2
5			PAD-TRANS. M. ROSS #10042		2
7		1/2"DIA.	SLEEVING, CLEAR THERMOSET		A/R
8	SEE NOTE #3	RM20M-13	BURNDY CONTACT MALE		1
9	SEE NOTE #4	RCDX60-1	BURNDY CONTACT FEMALE		2
	R1		RESISTOR AB, CB, 1/4W	47Ω	1
	R2		↓	47Ω	1
	R3		RESISTOR AB, CB, 1/4W	47Ω	1
	R4		RESISTOR ELECTRA 1%	31.6K	1
	R5		↓	2.15K	1
	R6		↓	2.15K	1
	R7		RESISTOR ELECTRA 1%	46.4K	1
	R8		RESISTOR WL60-T2 1%	9.09K	1
	R9		RESISTOR AB, CB, 1/4W 1%	47Ω	1
	R10		RESISTOR BOURNS 3007	500Ω	1
	R11		RESISTOR WL60-T2 1%	21.5K	1
	R12		RESISTOR WL60-T2 1%	9.09K	1
	R13		RESISTOR AB, CB, 1/4W 1%	2.2K	1
	R14		RESISTOR WL60-T2 1%	10K.	1
	R15		↓	825Ω	1
	R16		RESISTOR WL60-T2 1%	9.09K	1
	R17		RESISTOR AB, CB 1/4W	10Ω	1
	R18		RESISTOR WL60-T2 1%	F.A.	1
	R19		↓	3.48K	1

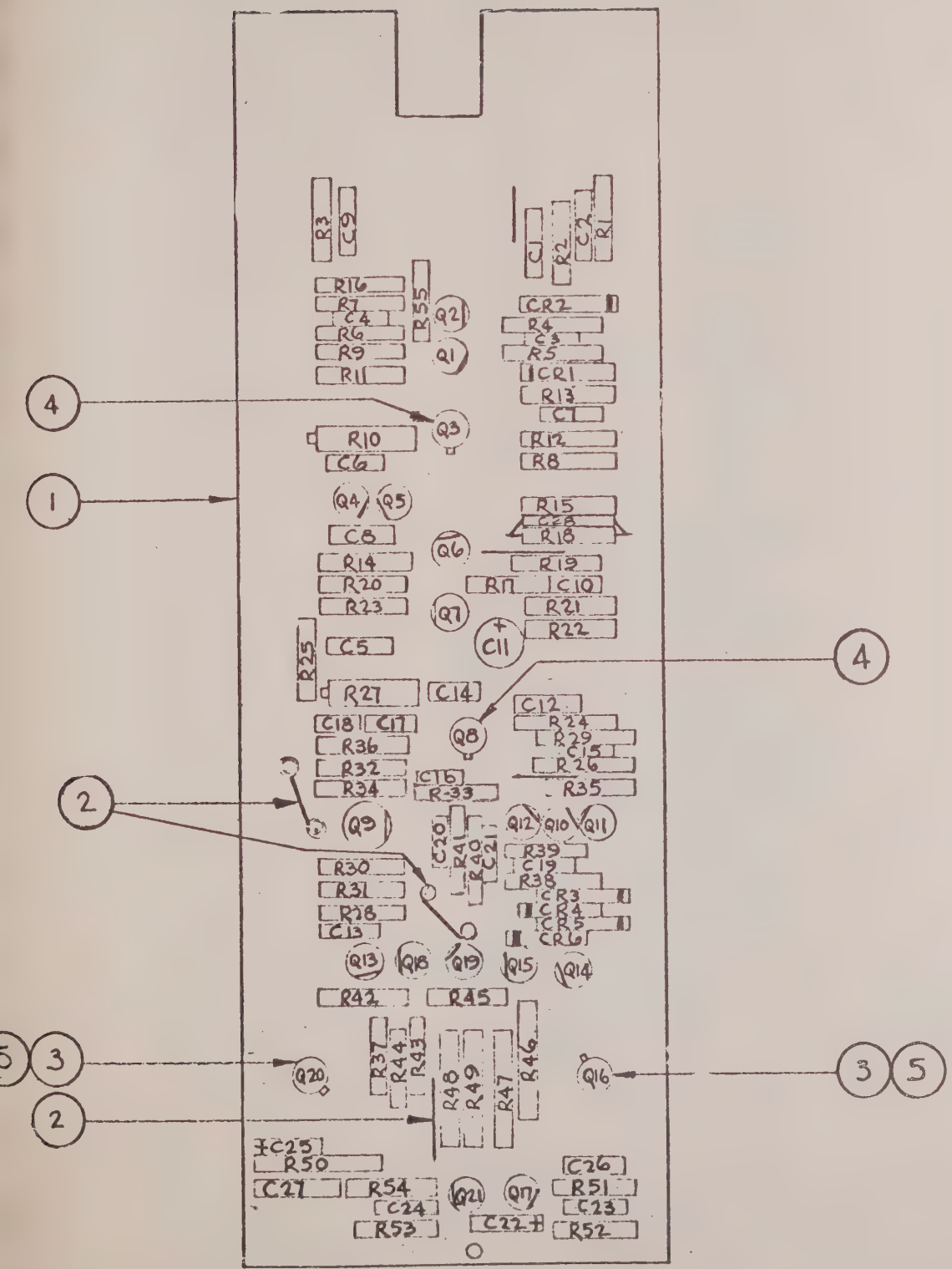
SIZE	CODE IDENT. NO.		
A	08539	A-018203	C
GFD-13-01		SHEET 2	

ITEM	SYMBOL	PART NO.	DESCRIPTION		QTY REQ'D	REV.
	R20		RESISTOR WL60-T2 1%	3.48K	1	
	R21		RESISTOR WL60-T2 1%	34.8K	1	
	R22		RESISTOR AB, CB, 1/4W	220Ω	1	
	R23		RESISTOR AB, CB, 1/4W	1K	1	
	R24		RESISTOR ELECTRA 1%	2.87K	1	
	R25		RESISTOR AB, CB, 1/4W	47Ω	1	
	R26		RESISTOR WL60-T2 1%	26.1K	1	
	R27		RESISTOR BOURNS 3007	500Ω	1	
	R28		RESISTOR WL60-T2 1%	7.5K	1	
	R29			26.1K	1	
	R30			9.09K	1	
	R31			9.09K	1	
	R32			F.A.	1	
	R33			JUMPER	1	
	R34			1K	1	
	R35			1.47K	1	
	R36		RESISTOR WL60-T2 1%	10K	1	
	Q1		TRANS. FAIRCHILD	2N4250	1	
	Q2		TRANS. G.E.	2N3856A	1	
	Q3		TRANS, U.C.	2N5454	1	
	Q4		TRANS, FAIRCHILD	2N4250	1	
	Q5		TRANS, FAIRCHILD	2N4250	1	
	Q6		TRANS, G.E.	2N3856A	1	
	Q7		TRANS, G.E.	2N3856A	1	
	Q8		TRANS, U.C.	2N5454	1	
	Q9		TRANS, SPRAGUE	TD101	1	
	Q10		TRANS, FAIRCHILD	2N4250	1	
	Q11			2N4250	1	
	Q12		TRANS, FAIRCHILD	2N4250	1	
	Q13		TRANS, G. E.	2N3856A	1	
	Q14			2N3856A	1	
	Q15		TRANS, G.E.	2N3856A	1	
	Q16		TRANS, SPRAGUE	TN53	1	
	Q17		TRANS, FAIRCHILD	2N4250	1	
	Q18		TRANS, G.E.	2N3856A	1	
	Q19		TRANS, FAIRCHILD	2N4250	1	
	Q20		TRANS, MOTOROLA	2N2904	1	
	Q21		TRANS, G.E.	2N3856A	1	
	C1		CAPACITOR RMC +80-20% 100V.	.1uF	1	
	C2			.1uF	1	
	C3			.01uF	1	
	C4		CAP, RMC +80-20%100V.	.01uF	1	
	C5		CAP, RMC +80-20%100V.	.1uF	1	
	C6		CAP, DURMICA DM-10	33pF	1	
	C7		CAP, DURMICA DM-10	22pF	1	
	C8		CAP, DURMICA DM-19	3320pF	1	
	C9		CAP, RMC +80-20%100V.	.1uF	1	
	C10		CAP, DURMICA DM-10	15pF	1	

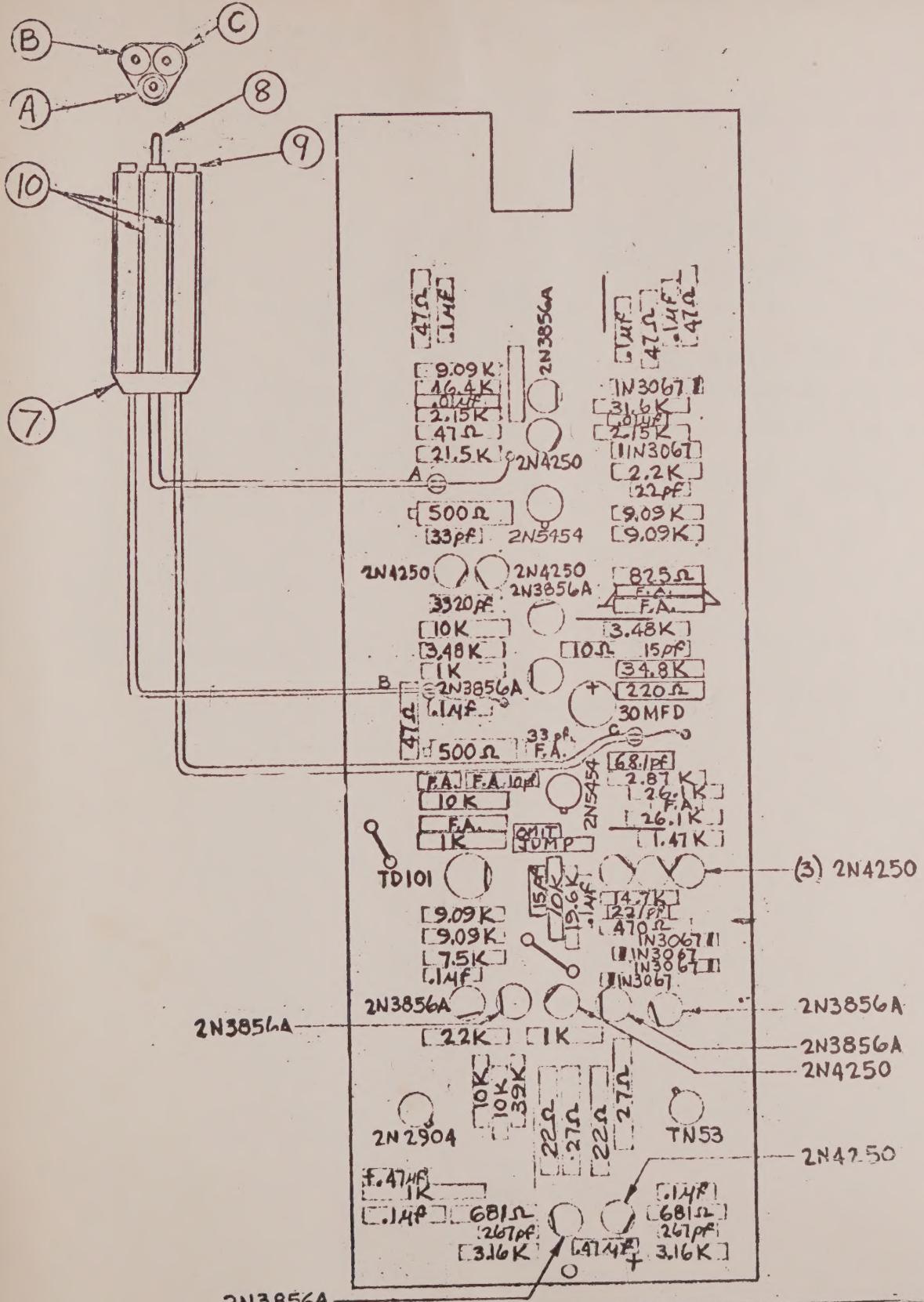
SIZE	CODE IDENT. NO.		
A	08539	A-018203	C
GFD-13-01		SHEET	3

ITEM	SYMBOL	PART NO.	DESCRIPTION		REV. QTY REQ'D
	C11	DY-015890-03	CAP. 25V	30uF	1
	C12		CAP, DURMICA DM-10	68.1pF	1
	C13		CAP, RMC +80-20%100V.	.1uF	1
	C14		CAP, DURMICA NOM. F.A.	33pF	1
	C15		↓	F.A.	1
	C16		↓	OMIT	1
	C17		CAP, DURMICA NOM F.A.	10pF	1
	C18		↓	F.A.	1
	C19		CAP, DURMICA DM-10	221pF	1
	C20		CAP, DURMICA DM-10	15pF	1
	C21		CAP, RMC +80-20%100V.	.1μf	1
	C22		CAP, SPRAGUE 35V 20%	.47uF	1
	C23		CAP, DURMICA DM-10	267pF	1
	C24		CAP, DURMICA DM-10	267pF	1
	C25		CAP, SPRAGUE 35V 20%	.47uF	1
	C26		CAP, RMC +80-20% 100V.	.1uF	1
	C27		CAP, RMC +80-20%100V.	.1uF	1
	CR1		DIODE C.D.C.	IN3067	1
	CR2		↓	IN3067	1
	CR3		↓	IN3067	1
	CR4		↓	IN3067	1
	CR5		↓	IN3067	1
	CR6		DIODE C.D.C.	IN3067	1
	C28	SEE NOTE *5	CAP. DURMICA DM-10	F.A.	1

SIZE	CODE IDENT. NO.		
A	08539	A 018203	C
GFD-13-01		SHEET	4



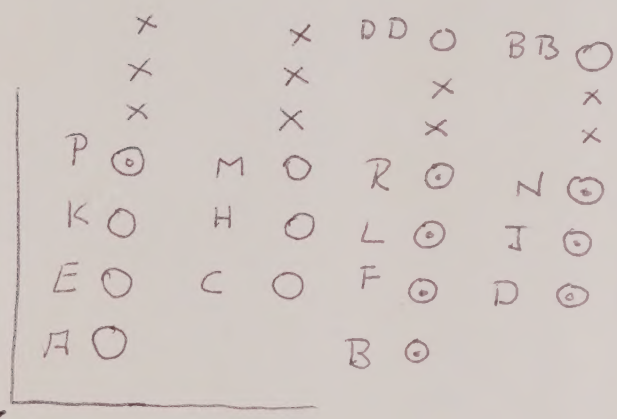
DATA CONTROL SYSTEMS, INC.	A 018203	C
GFD-13-01	SHEET 5	



DATA CONTROL SYSTEMS, INC.	A-018203
GFD-13-01	SHEET 6

MAINTENANCE NOTES

CONNECTOR LETTERING FOR HOOKUP



X. DENOTES BLANK HOLE

⊙ DENOTES MINIATURE SHIELDED SOCKET CONNECTION

○ STRAIGHT PIN

REFERENCE: LOWER LEFT HAND CORNER LOOKING FORWARD, FROM THE REAR VIEW.